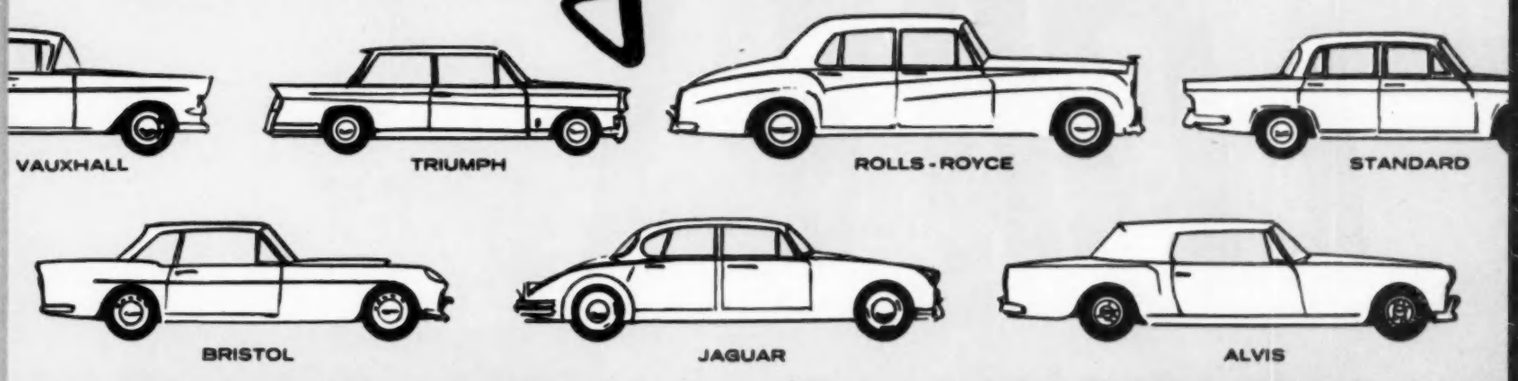
# THE ENGINEER

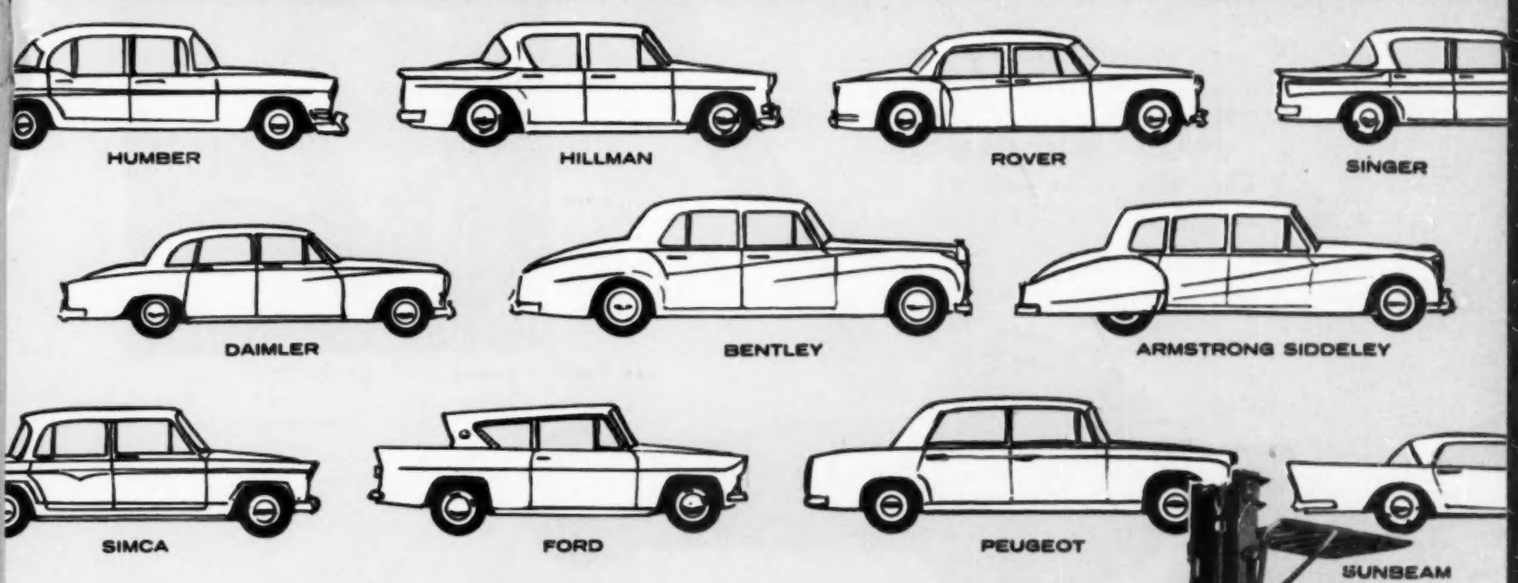
DECEMBER 30, 1960 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS



Coventry Climax fork lift trucks

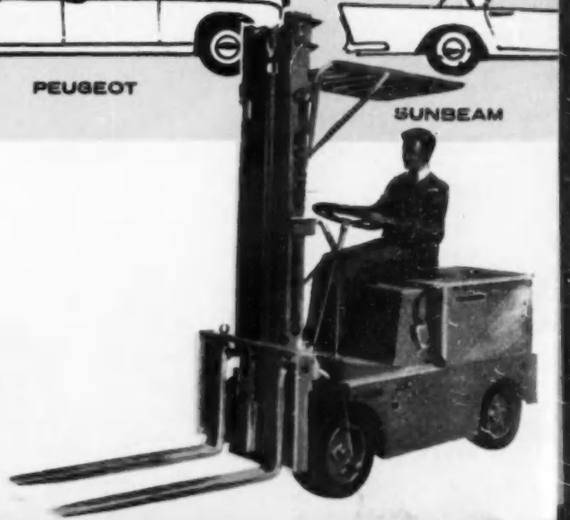



are used by all these car manufacturers




It is well known that the Motor Industry is one of the most advanced industries in the efficiency of it's handling methods. It is therefore significant that so many car manufacturers have adopted fork truck handling in their organisations ***and have chosen***

Coventry Climax



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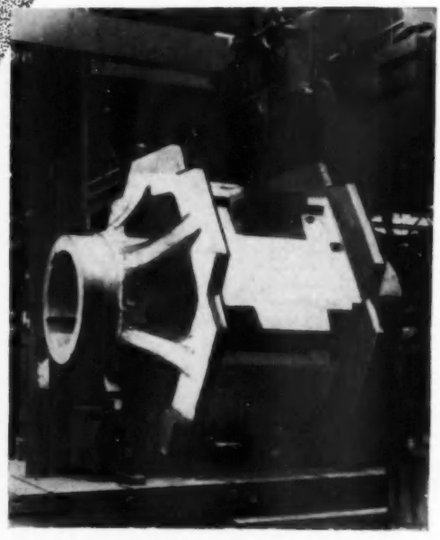

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# THE ENGINEER

*Established* 1856

No. 5475 **DECEMBER 30, 1960** VOL. 210

## EDITORIAL CONTENTS


| | | |
|---|---|---|
| **Leading Articles** | Transport Reorganisation | 1075 |
| | A Great Indispersible Clot | 1076 |
| **Articles** | | |
| | 100 Years Ago | 1076 |
| | Large Bore Marine Diesel Engine | 1077 |
| | Reorganisation of the Nationalised Transport Undertakings | 1079 |
| *D. F. Galloway* | Machine Tool Research, Design and Utilisation | 1081 |
| | Glass Level Control | 1082 |
| *M. H. Saadawi* | Investigation of Cut-Off and Throttle Governing of Petrol Engines | 1083 |
| *J. R. Linge* | Thermal Cycling Rigs for Nuclear Reactor Fuel Elements | 1093 |
| *Parker*, et al | Edge Cracking of a Steel Band Conveyor | 1099 |
| | Dounreay Fast Reactor. No. IV | 1105 |
| *T. Henry Turner* | Teaching of Metallurgy to Engineers | 1110 |
| | Powder Metallurgy | 1111 |
| *P. G. Marson* | Industry and the New Rating Bill | 1111 |
| | Hydraulic Pit Props for Temporary Floor Strengthening | 1113 |
| | Electricity Bulk Supply Tariff | 1114 |
| | Power Rise for "Dido" Research Reactor | 1114 |
| | Engineering and Shipbuilding Wages | 1114 |
| | Railway Electrification | 1114 |
| | Kent Coast Electric Services | 1114 |
| | Microwave Frequency Checking Equipment | 1114 |
| | Pulse Code Modulation Telephony | 1115 |
| | Punched Paper Tape Reader | 1115 |
| | Secondary Radar | 1115 |
| **Continental Affairs** | | |
| | 125th Anniversary of German Railways | 1117 |
| **American Scene** | | |
| | Launch of U.S.S. "Enterprise" | 1120 |
| **LETTERS** | Stiffness of a Crane Jib | 1108 |
| | Screwy Screw Threads | 1108 |
| | New Water Policy Foreshadowed? | 1108 |
| **BOOK REVIEWS** | | 1108 |
| **NEWS AND NOTES** | Technical Report | 1113 |
| | Personal and Business | 1116 |
| | British Patent Specifications | 1121 |
| | Forthcoming Engagements | 1122 |
| | Advanced Engineering Courses | 1122 |


**INDEX TO ADVERTISERS : PAGE 87** **CLASSIFIED ADVERTISEMENTS : PAGE 82**

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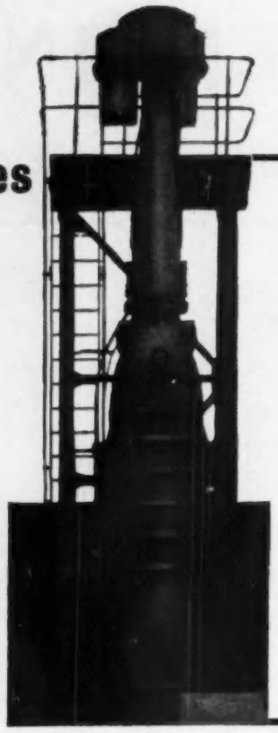
## relies on Bailey's valves



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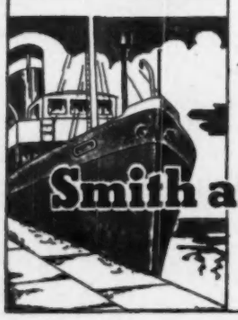

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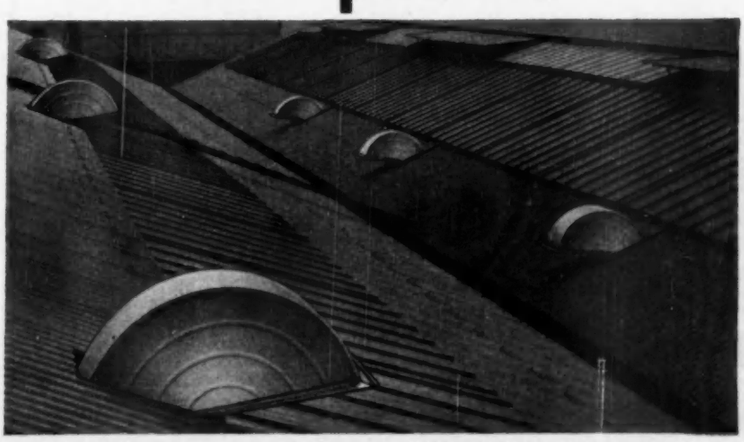

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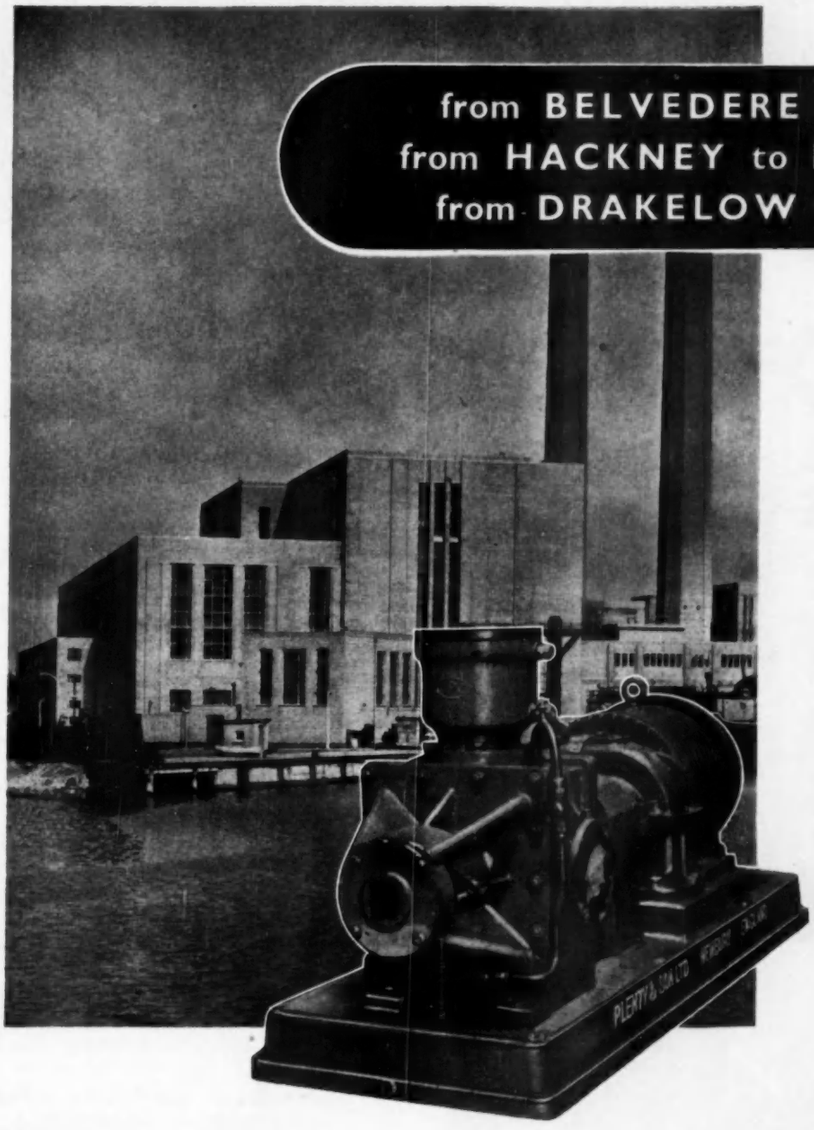


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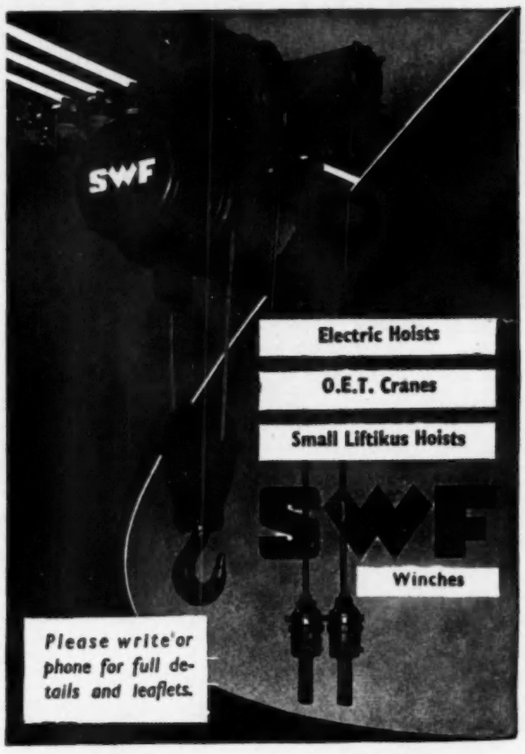


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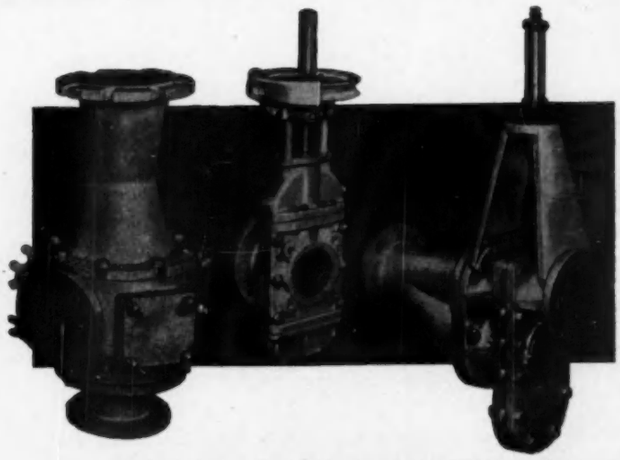

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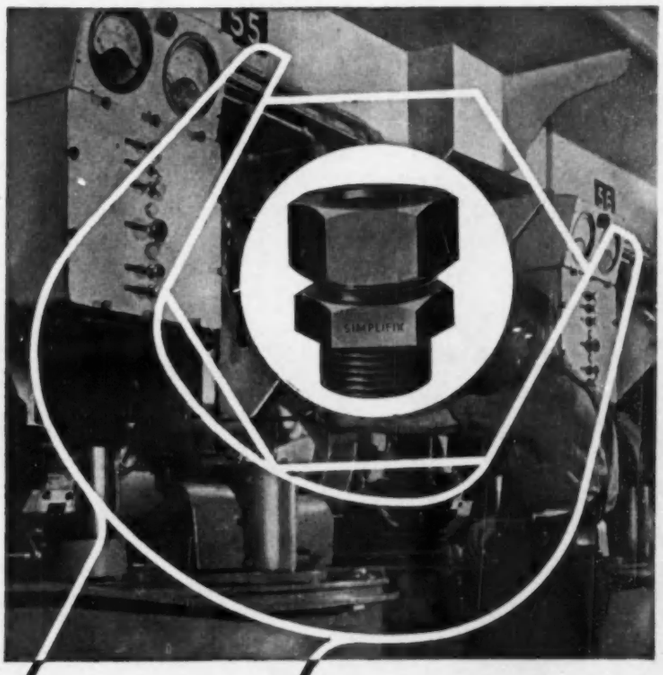


*The illustration shows centrifugal machines at the Plaistow Wharf Sugar Refinery of Tate and Lyle Ltd., where large numbers of Simplifix couplings are used.*

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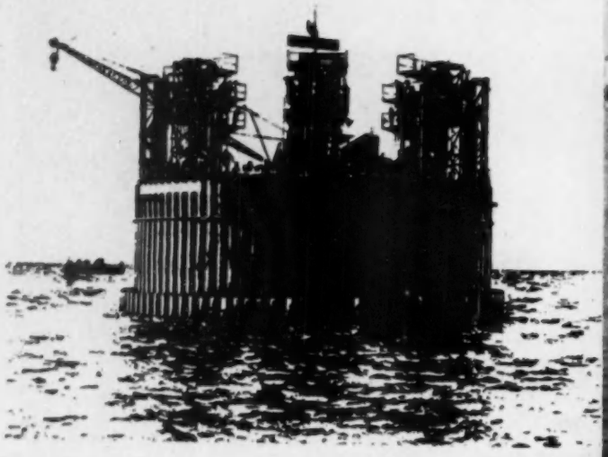

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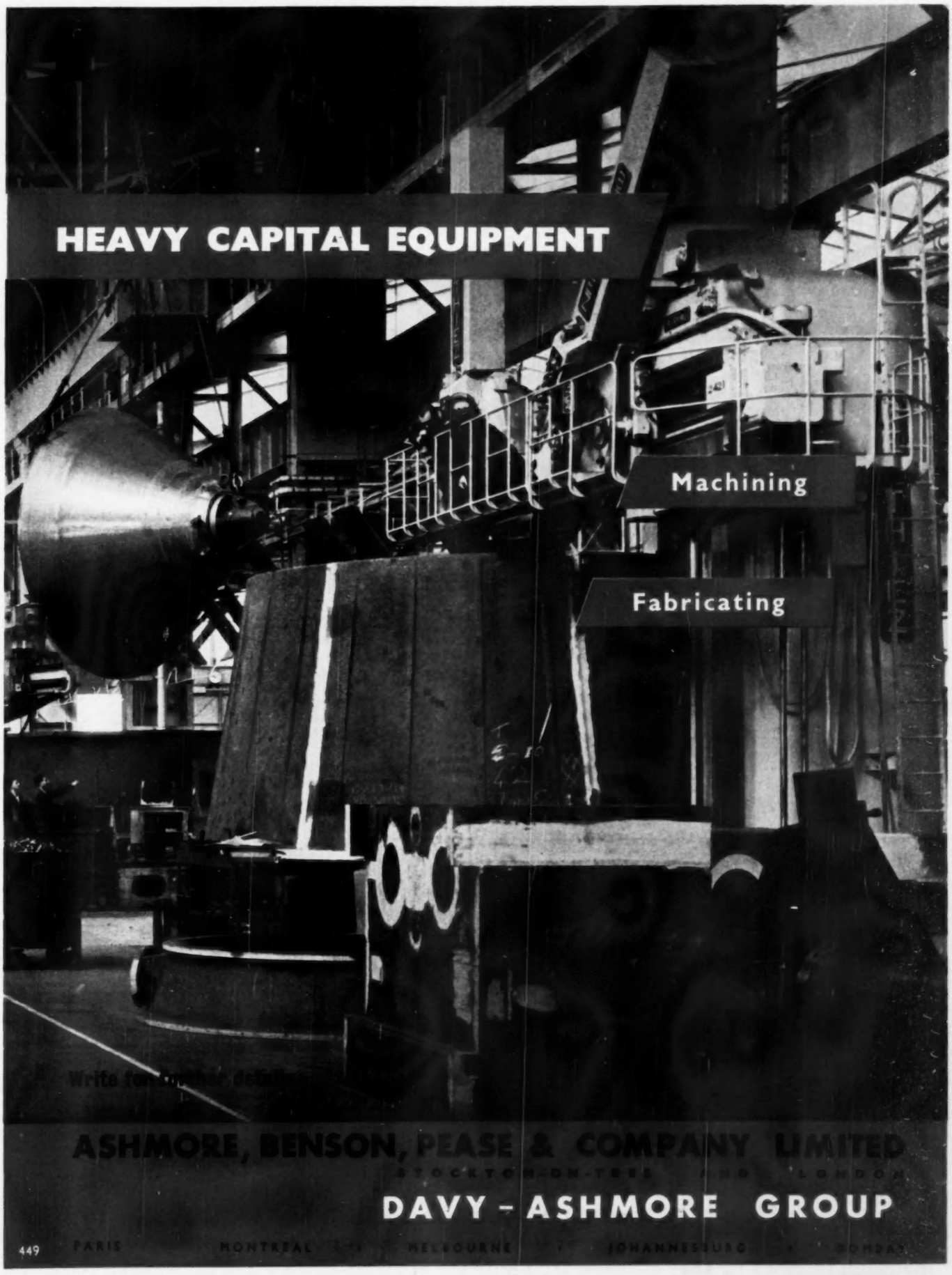


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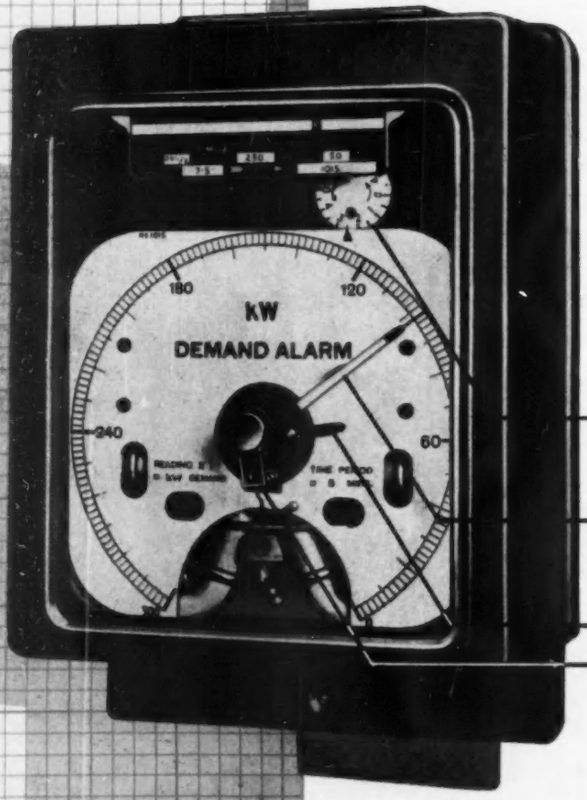


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**Has reached the top. To these, our salutation.**
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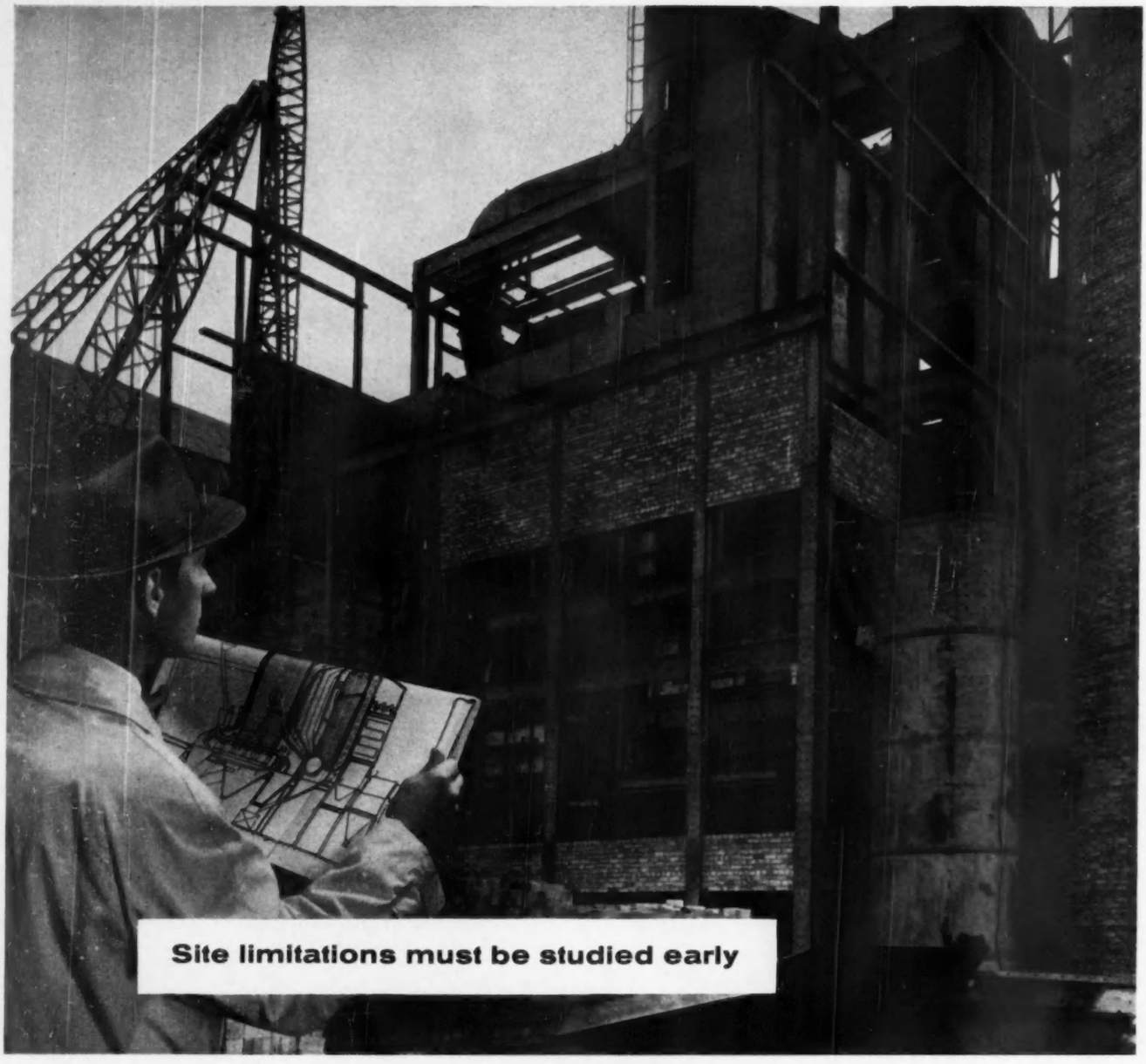


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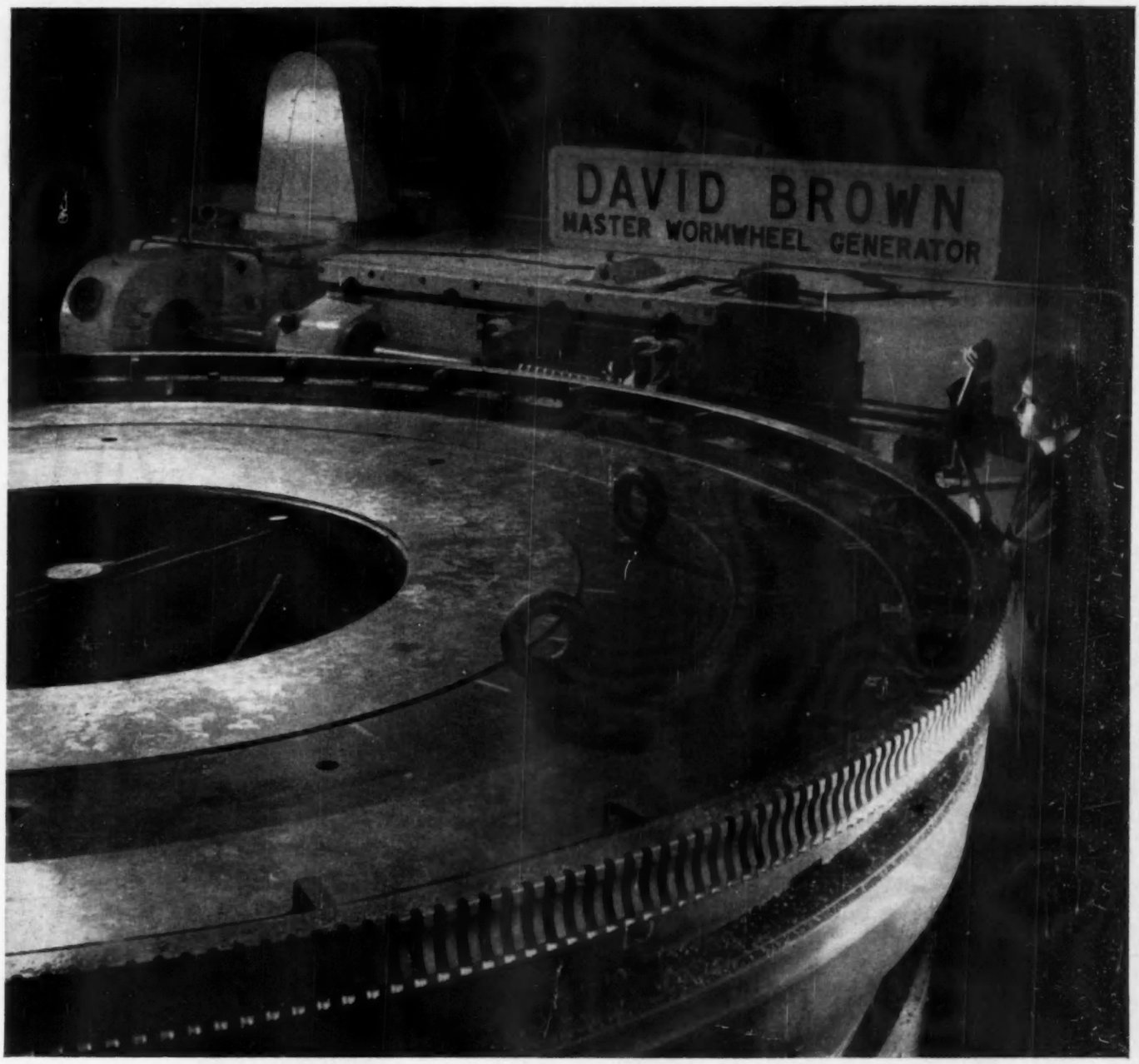


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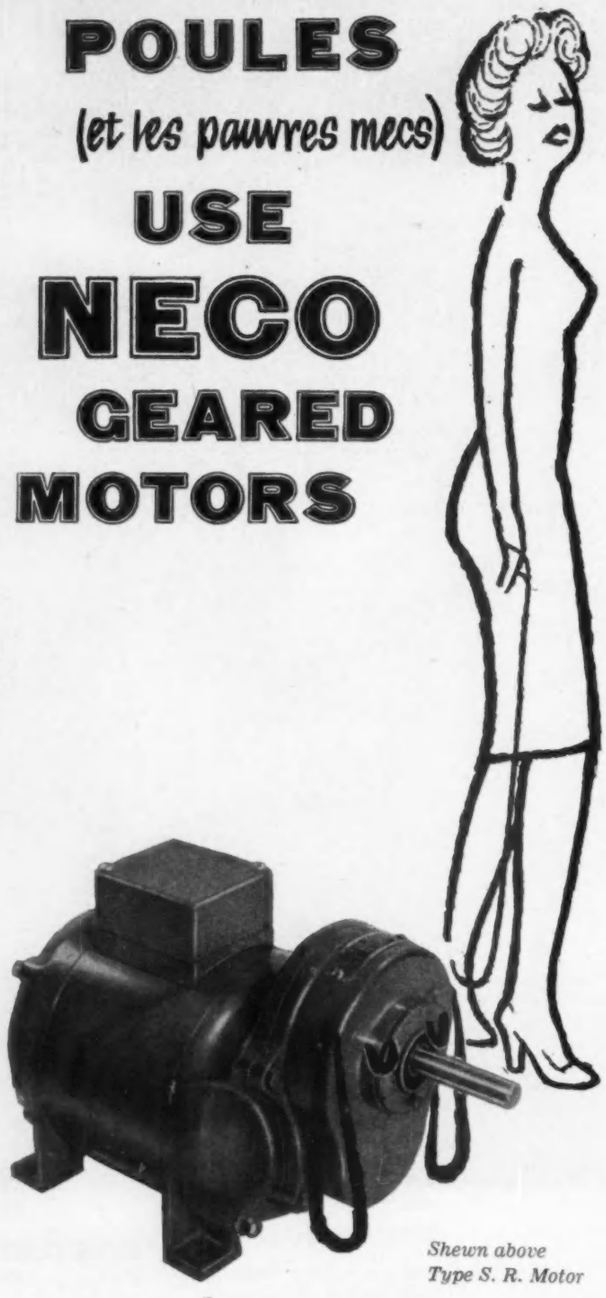

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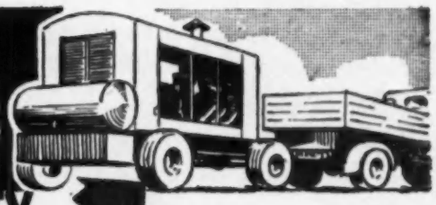

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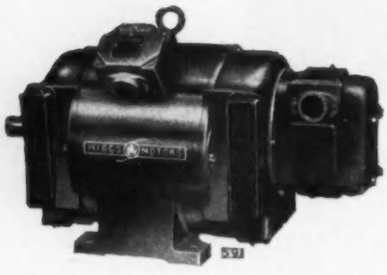

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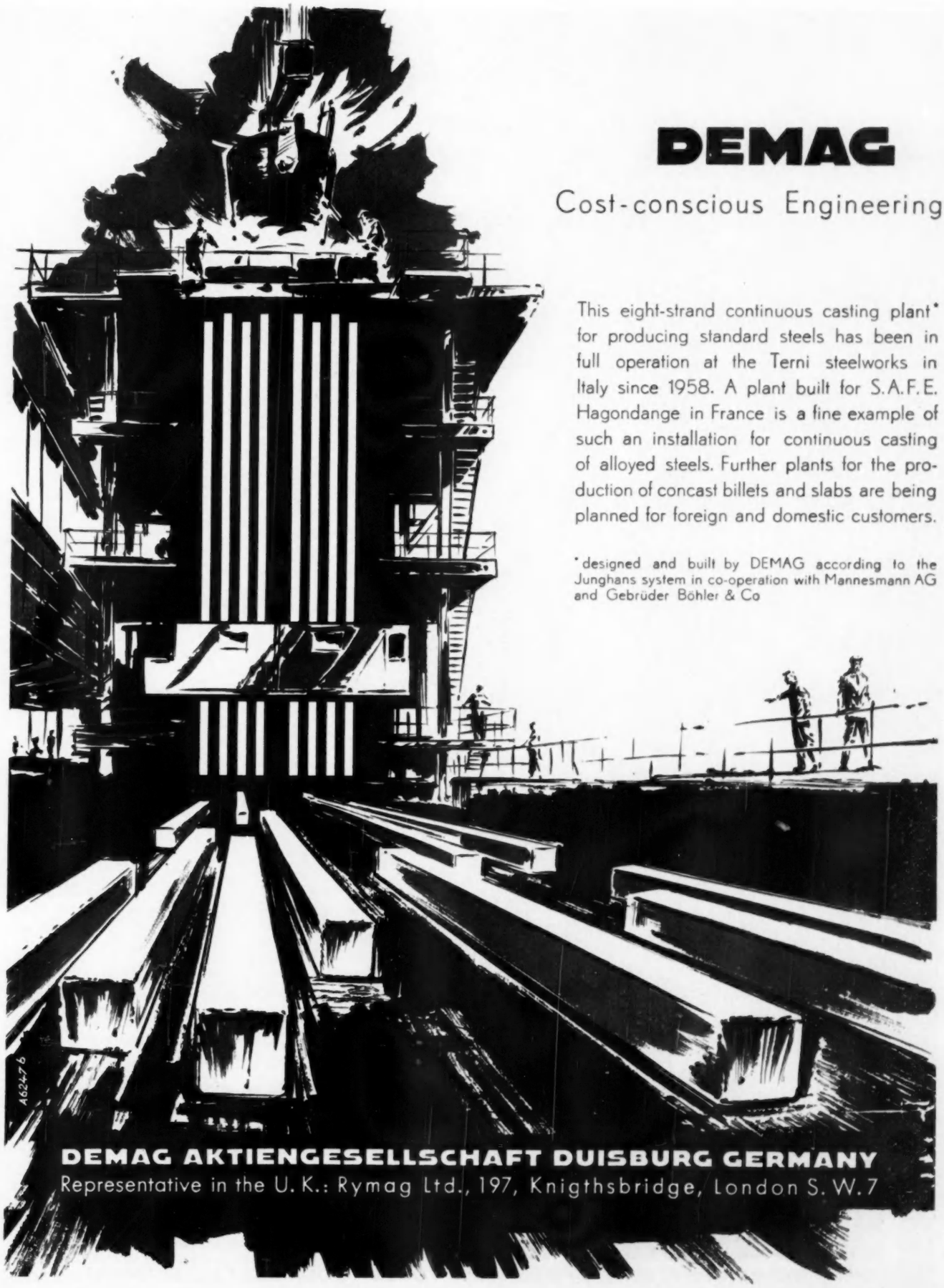

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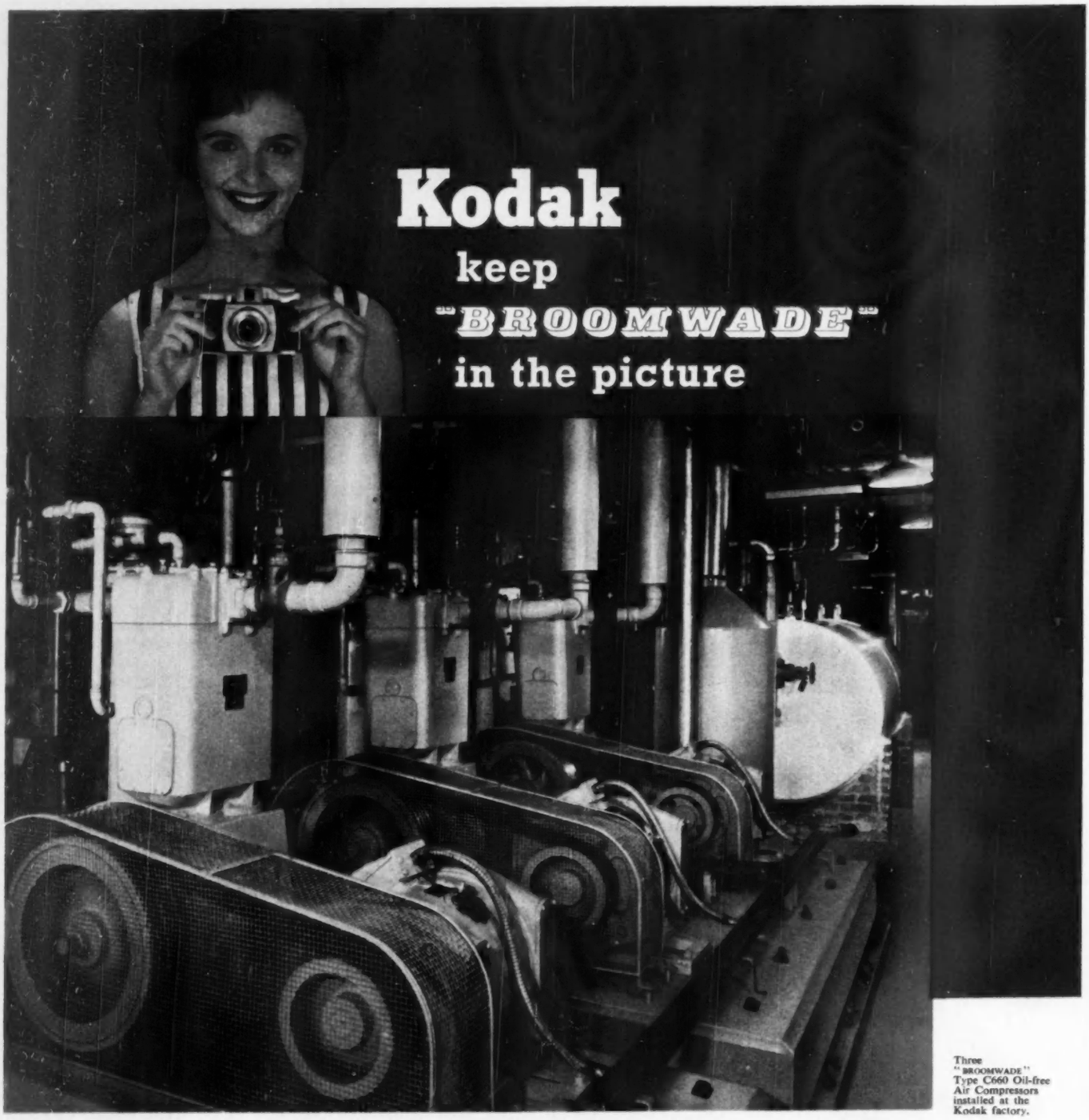


Three "BROOMWADE" Type C660 Oil-free Air Compressors installed at the Kodak factory.

Photograph by courtesy of Messrs. Kodak Limited

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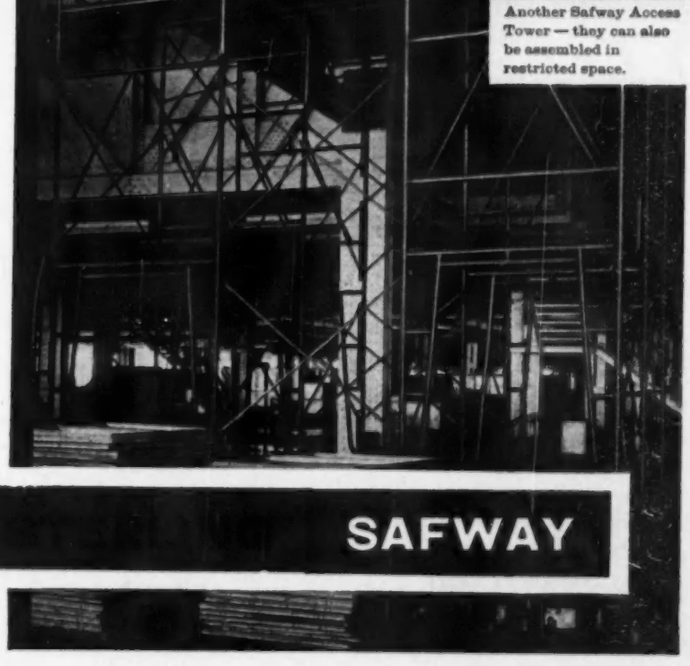

Another Safway Access Tower — they can also be assembled in restricted space.

## large area access platforms

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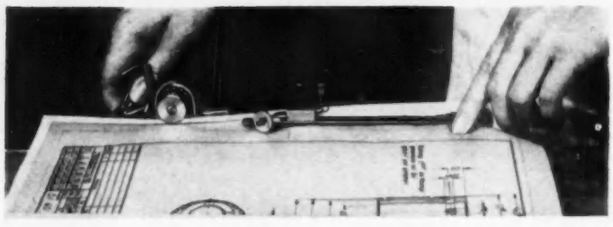
EDGE BIND with ADMEL TESA TAPES



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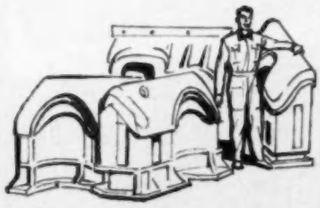

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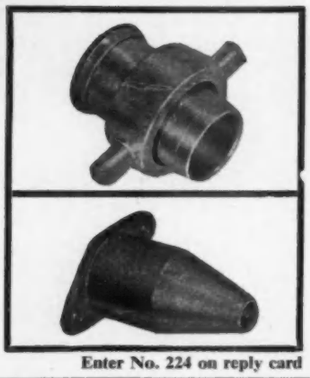

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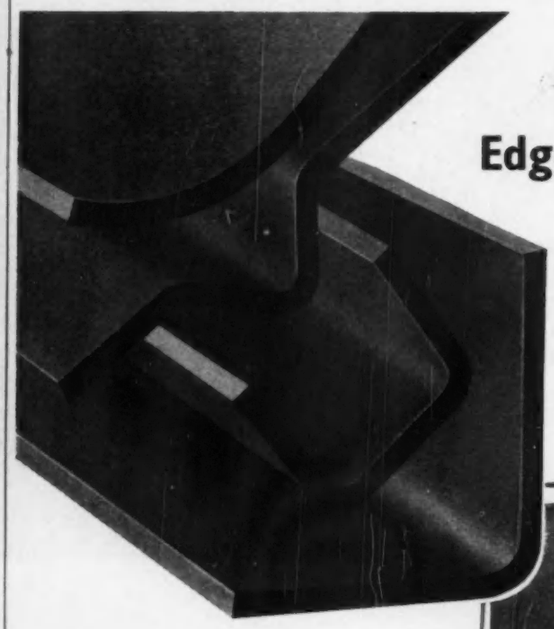

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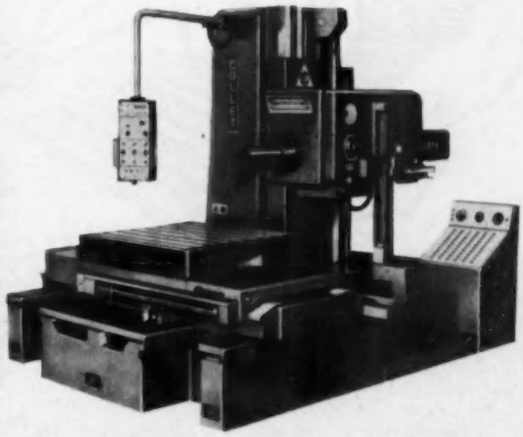

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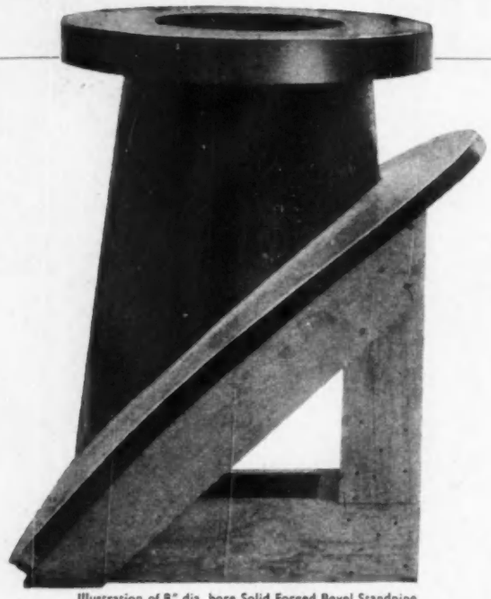

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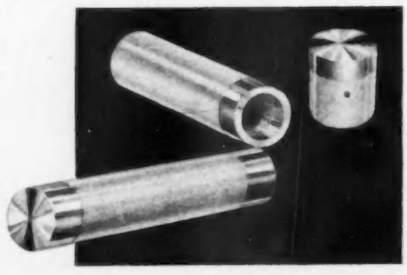

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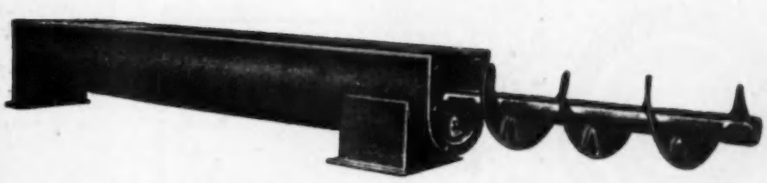

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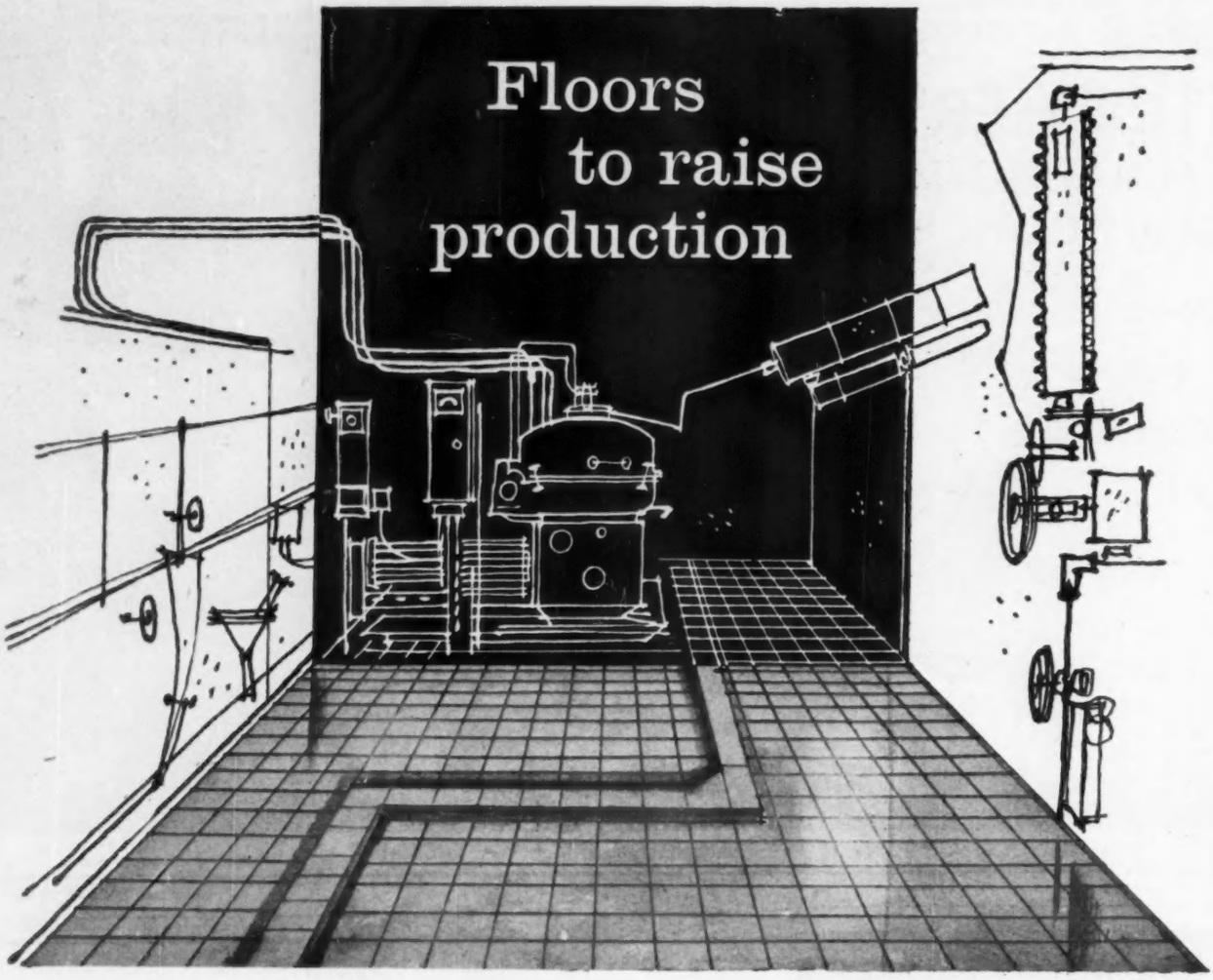

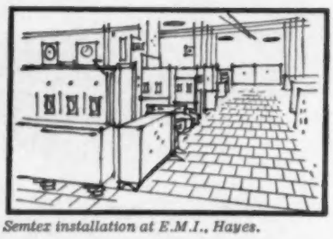

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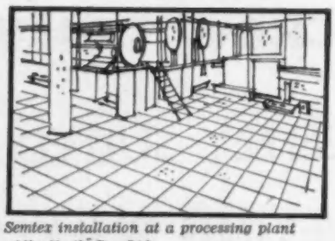

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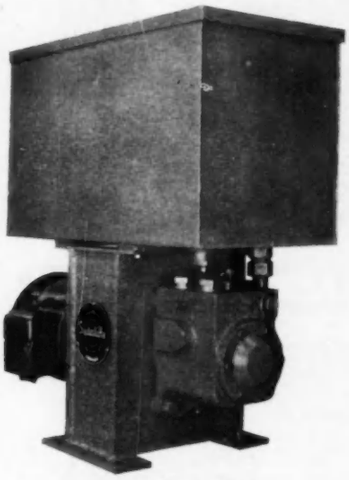

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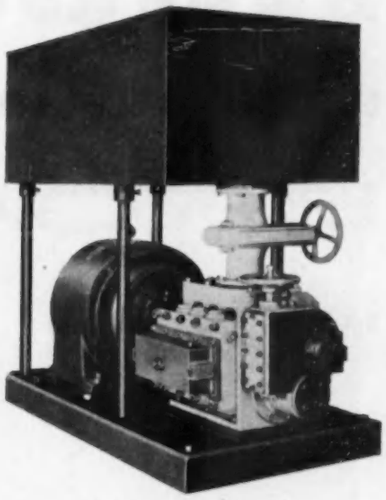

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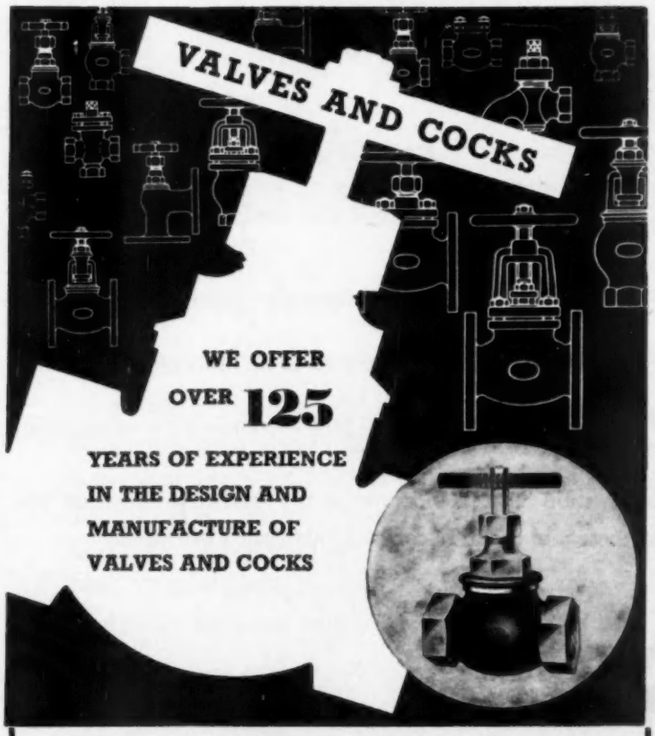


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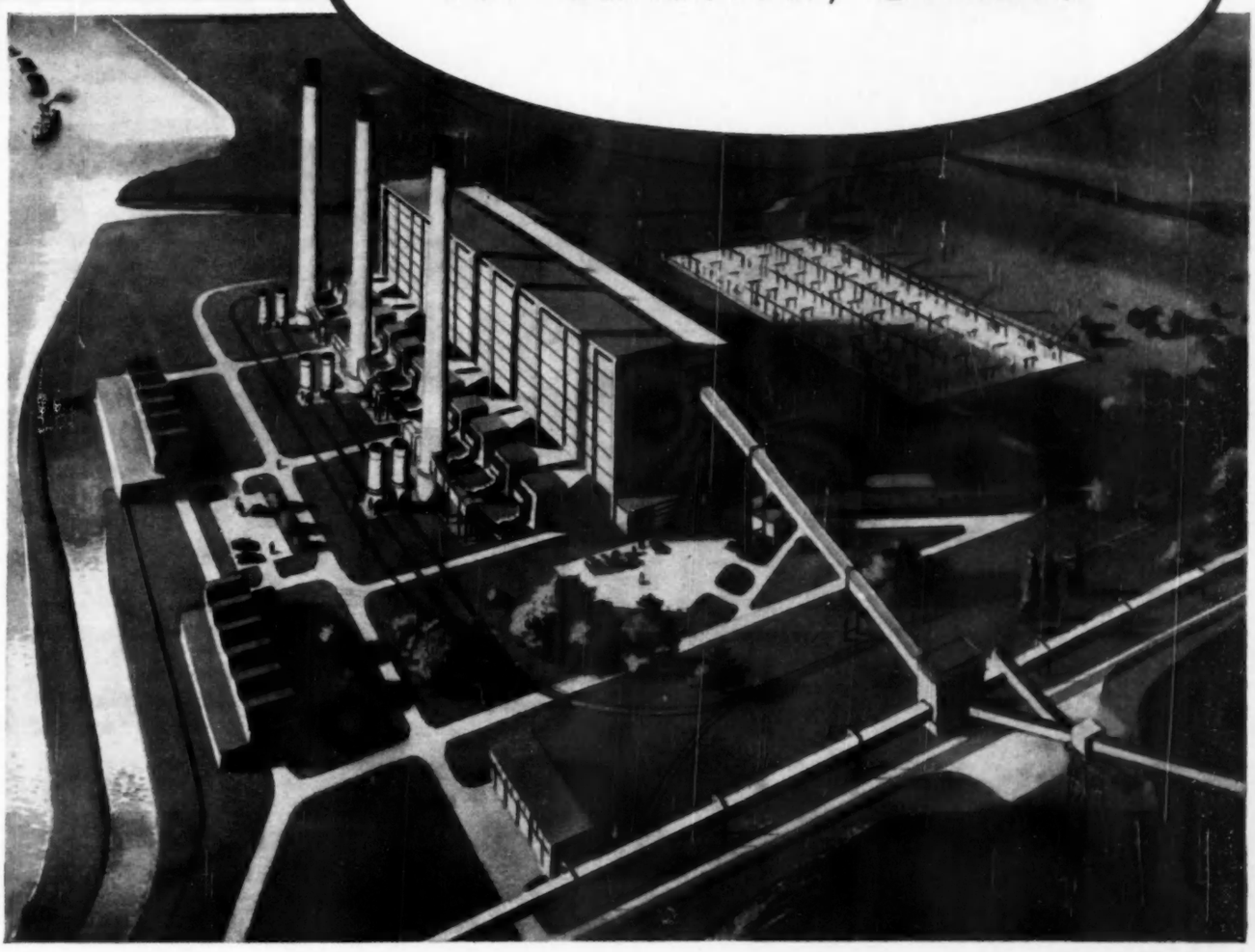

*From an original drawing supplied by the Hydro Electric Power Commission of Ontario*

THIS artist's impression shows the Lakeview Generating Station now being built beside Lake Ontario. With its planned capacity of 1,800 MW, it will be one of the world's largest thermal-electric plants. Two 300 MW turbine-generators have been ordered from AEI and the first will be installed in 1963. These generating sets, like all AEI equipment, will incorporate advanced design based on long experience.

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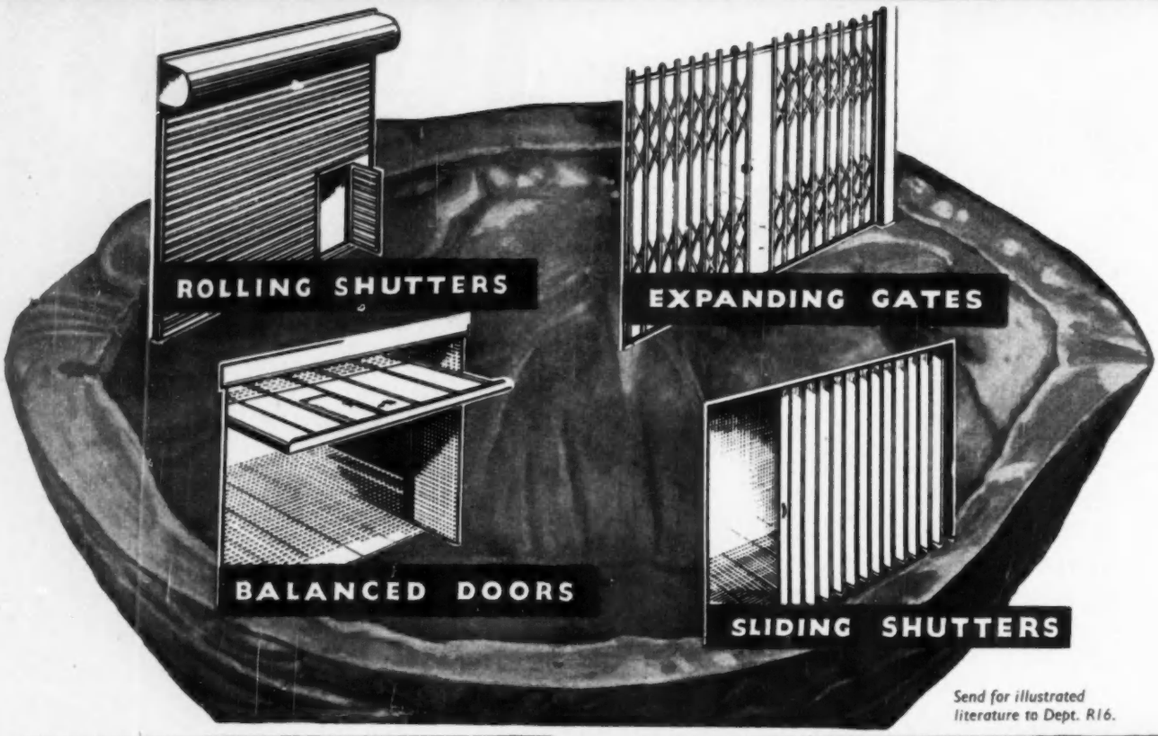


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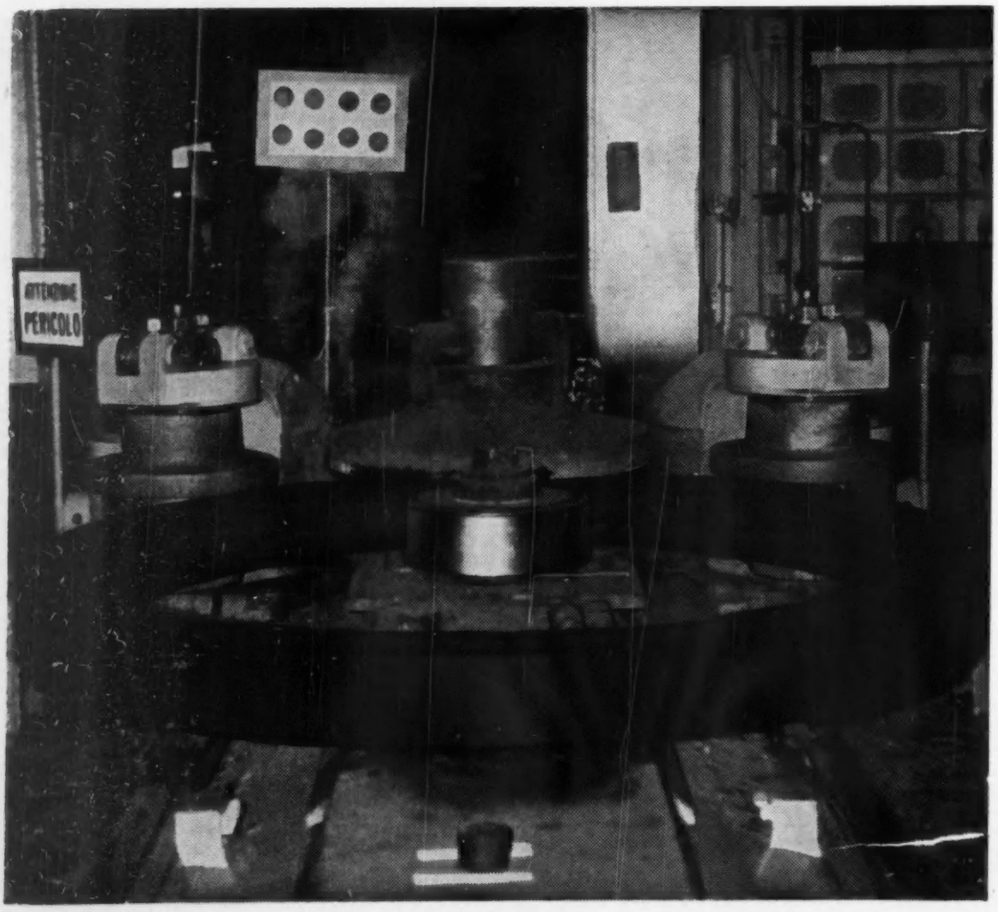


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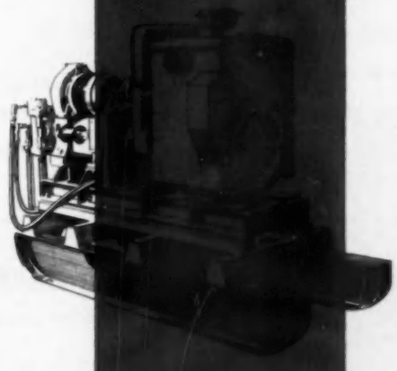

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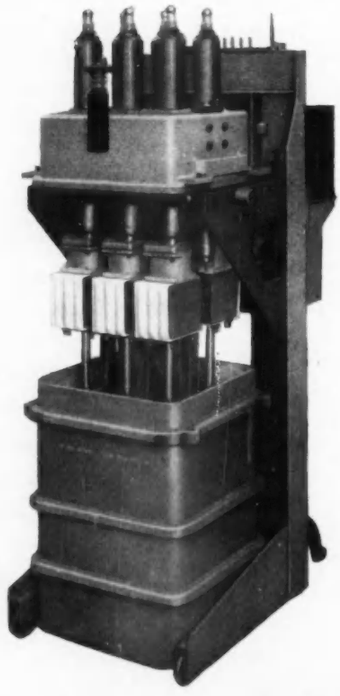

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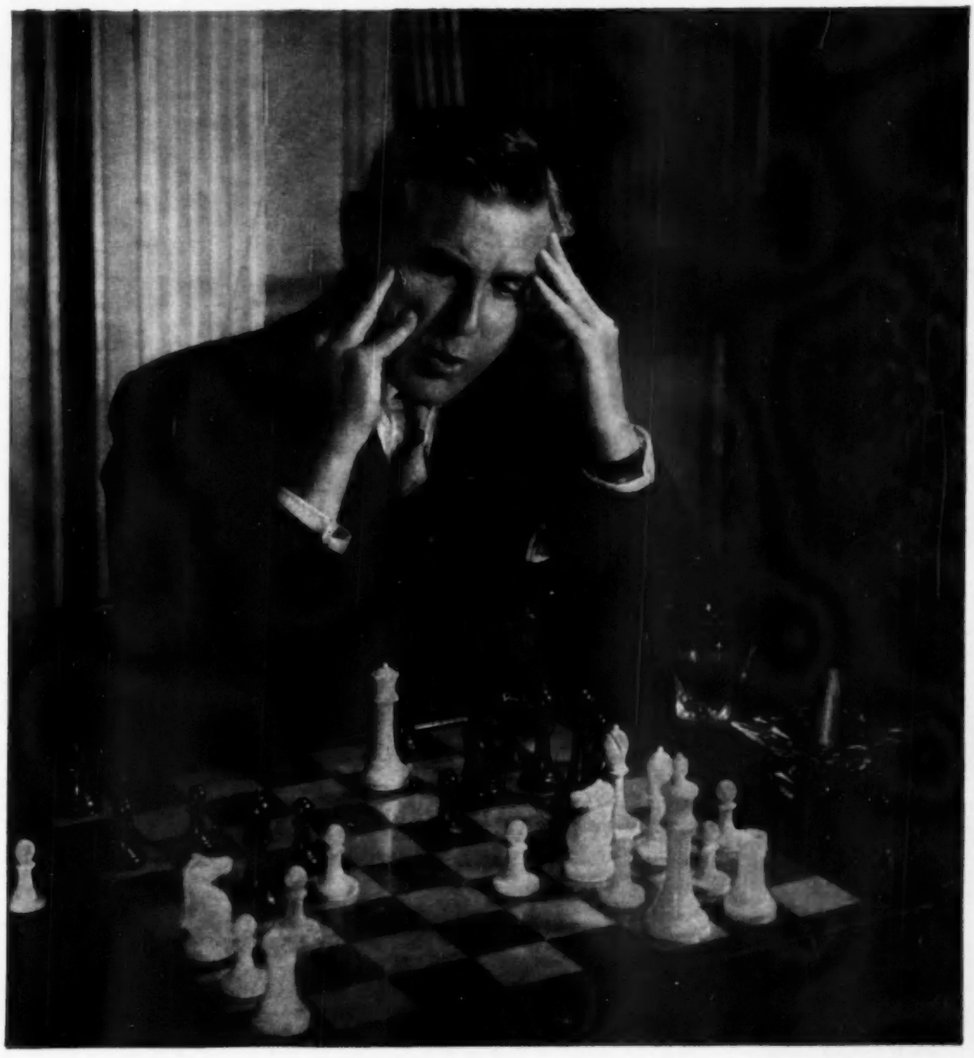

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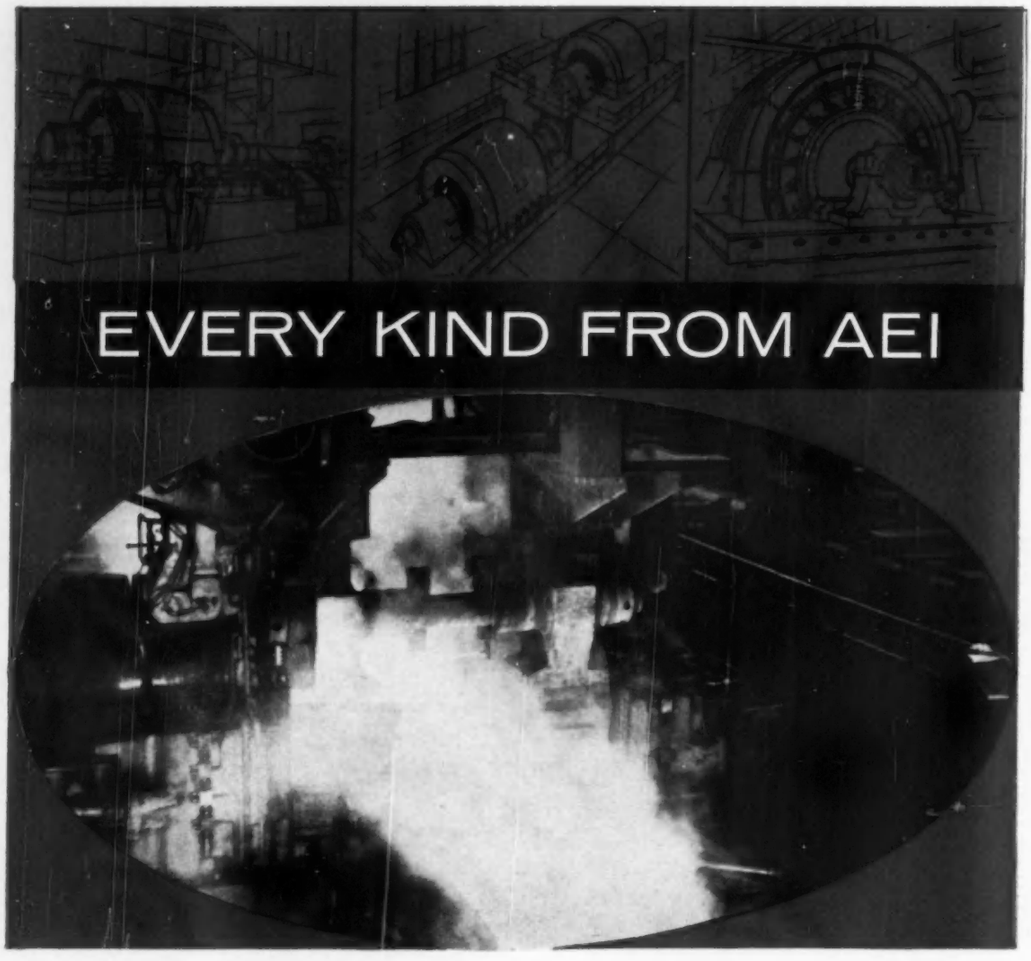


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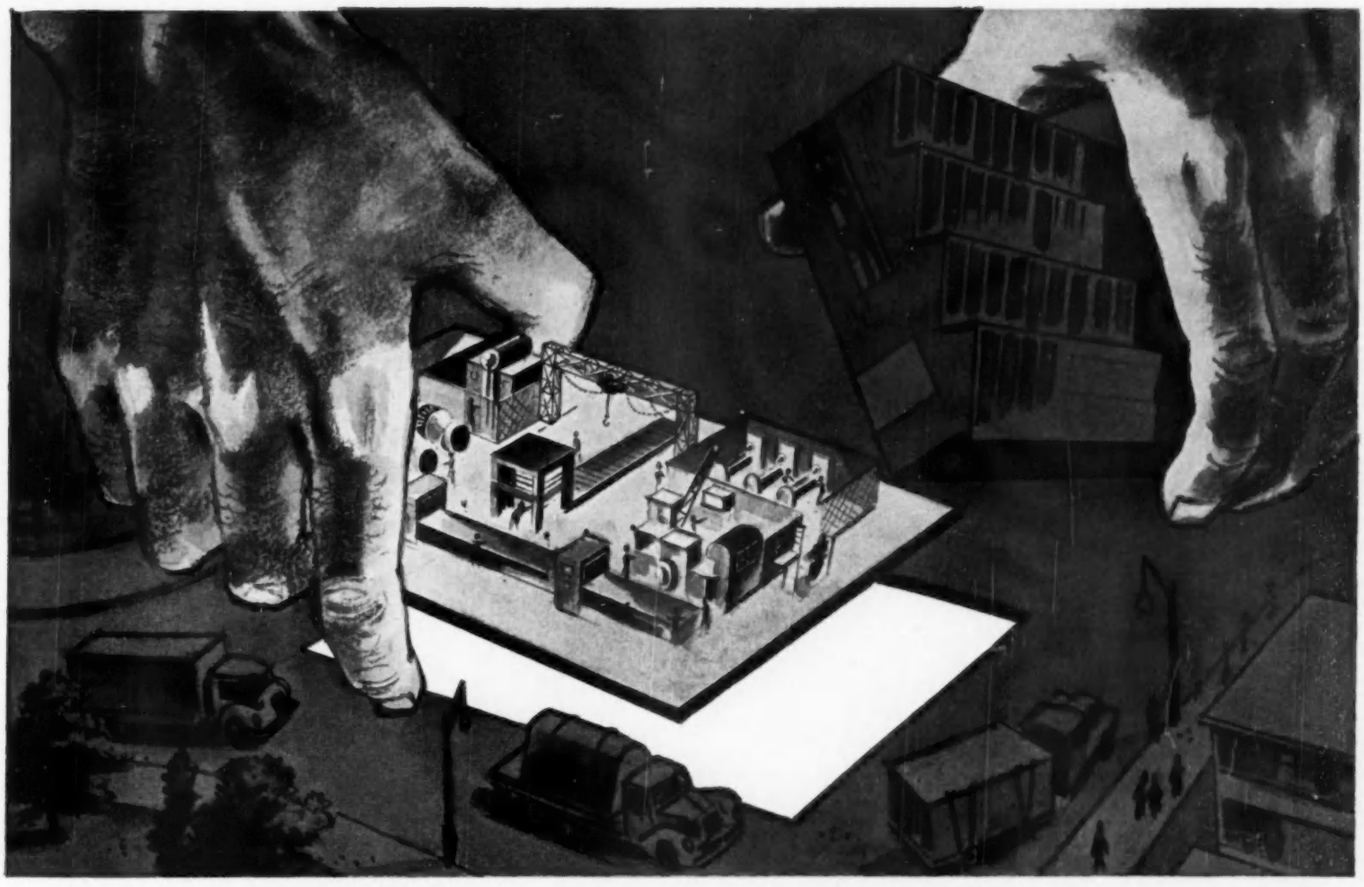

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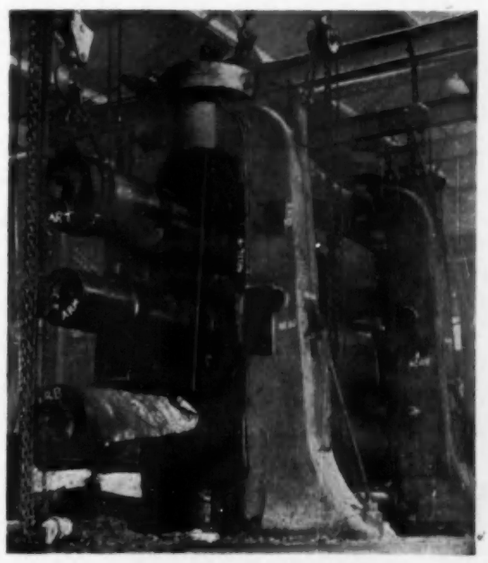

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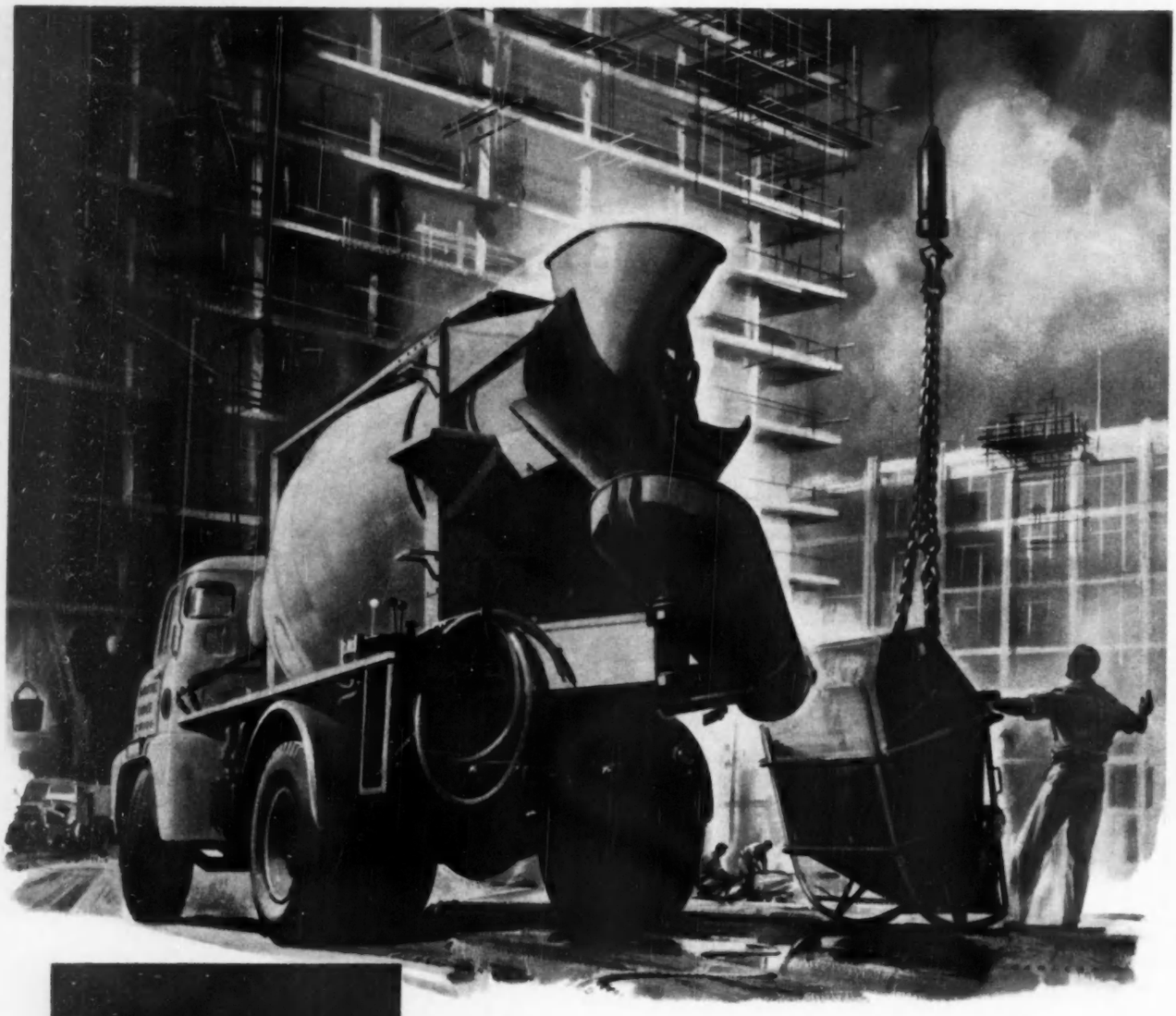

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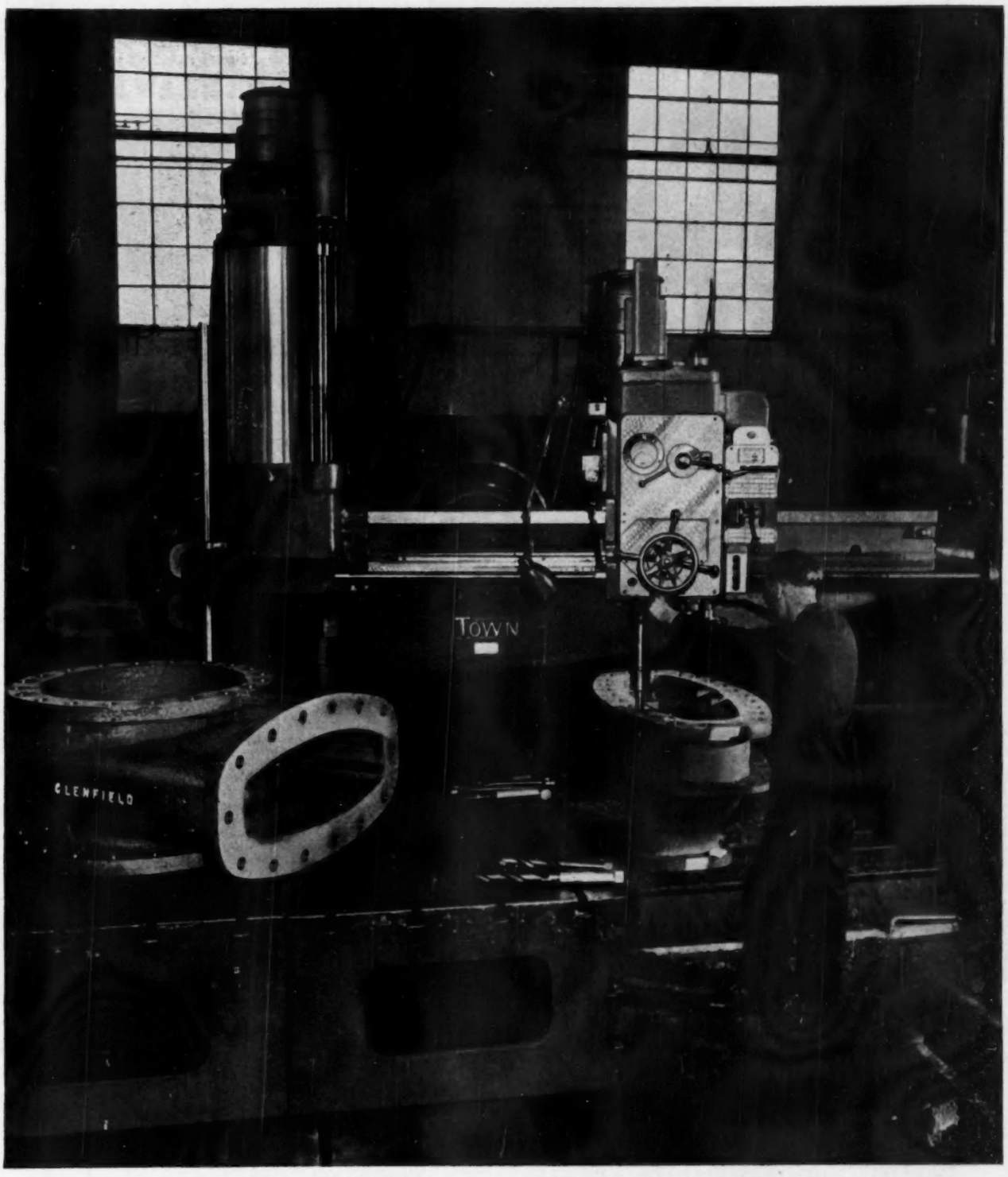


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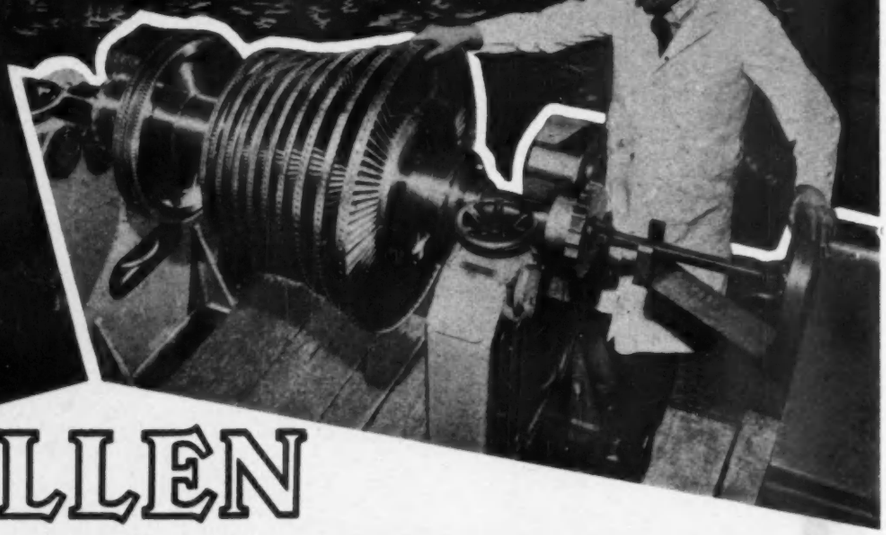

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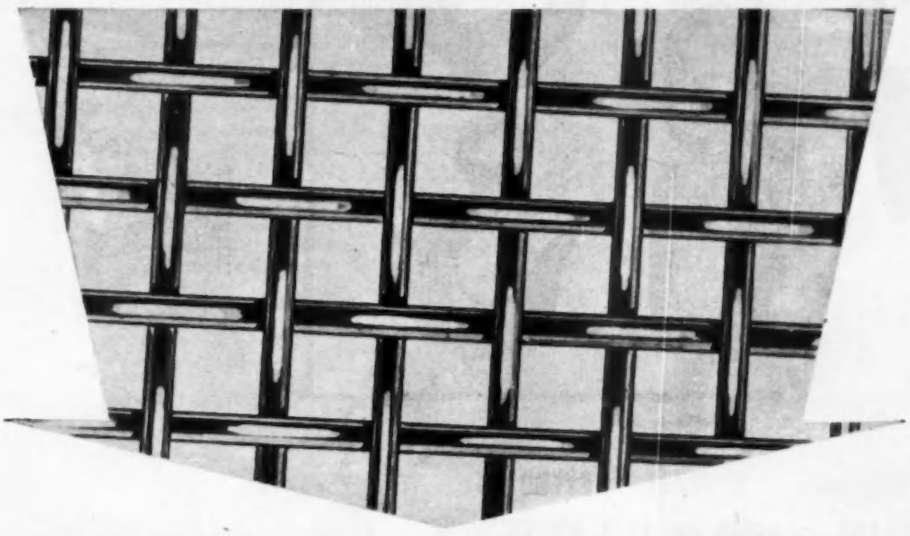

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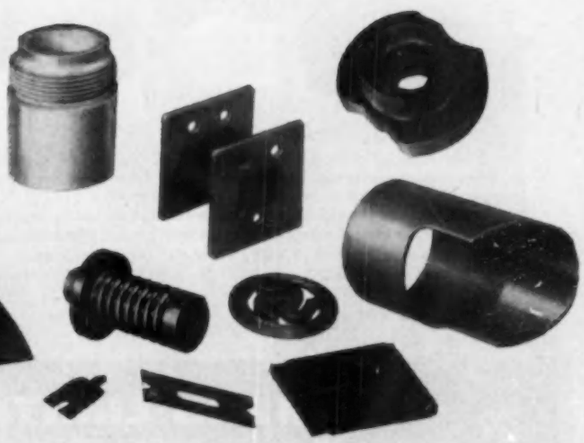

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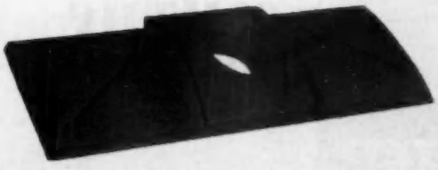

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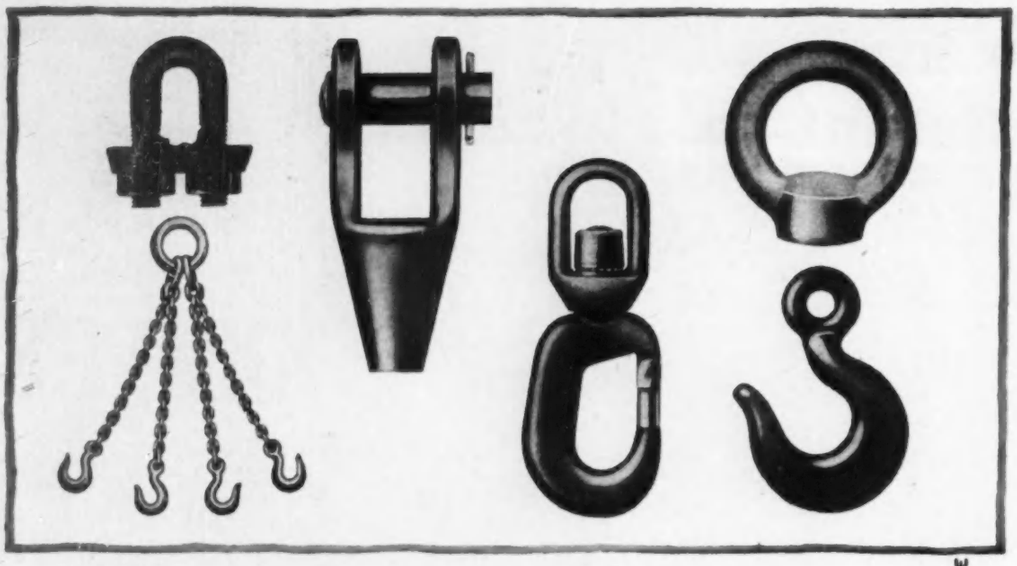

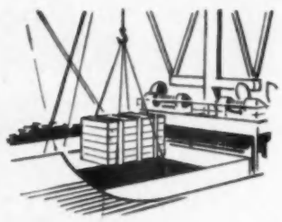

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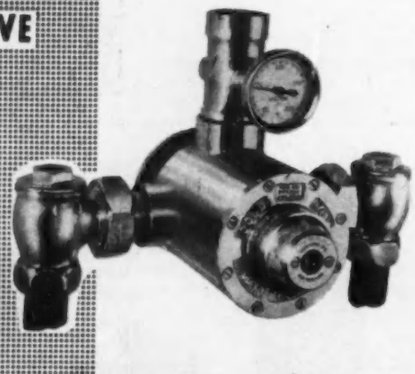

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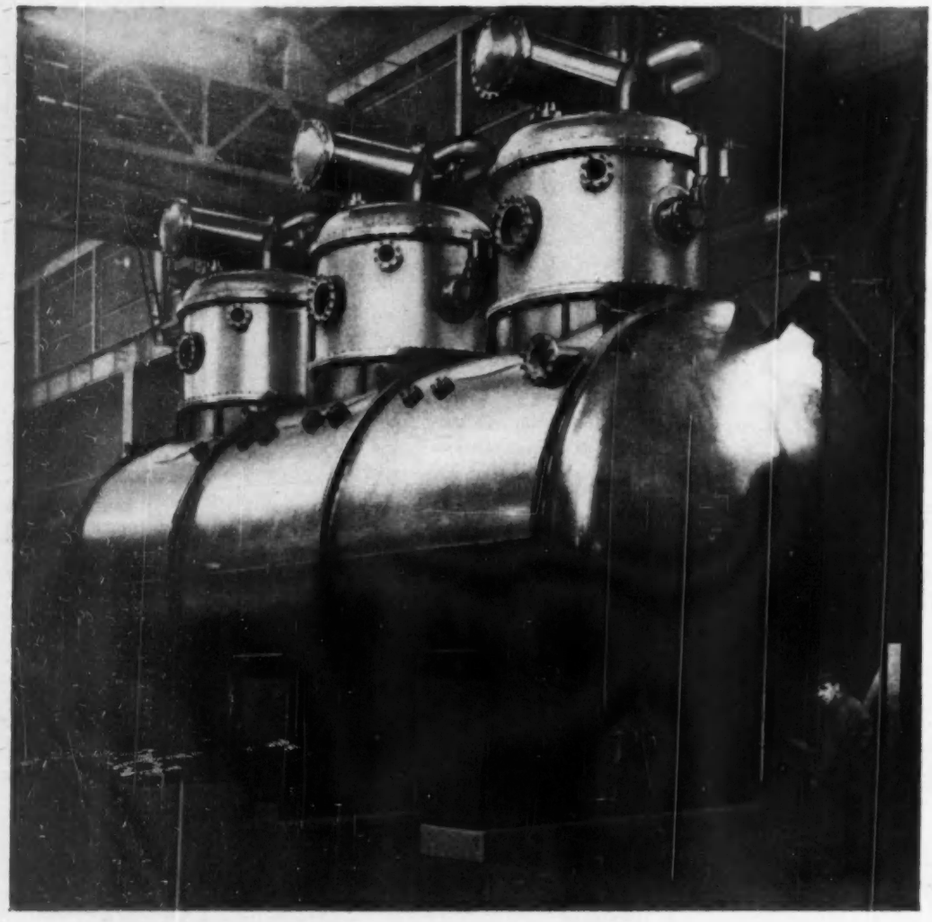

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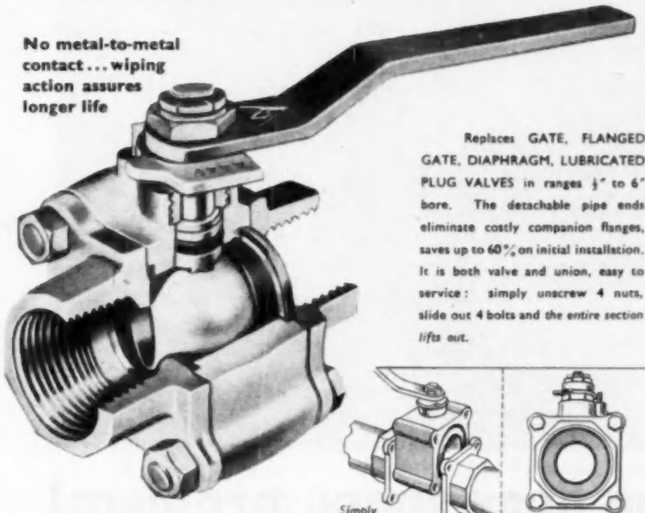

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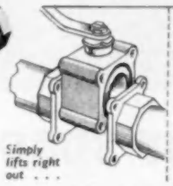

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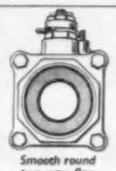

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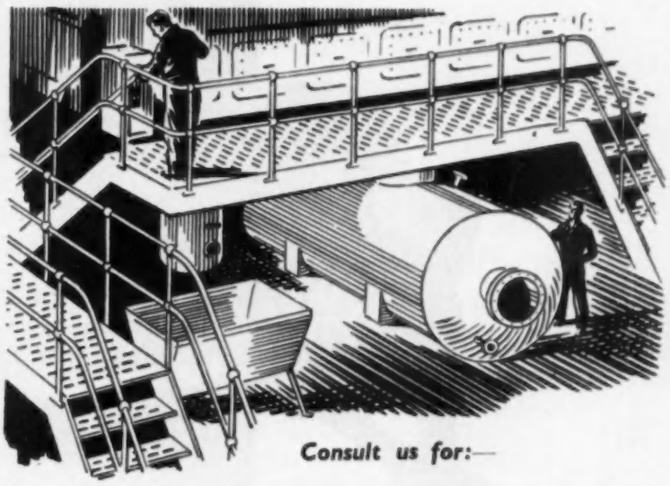

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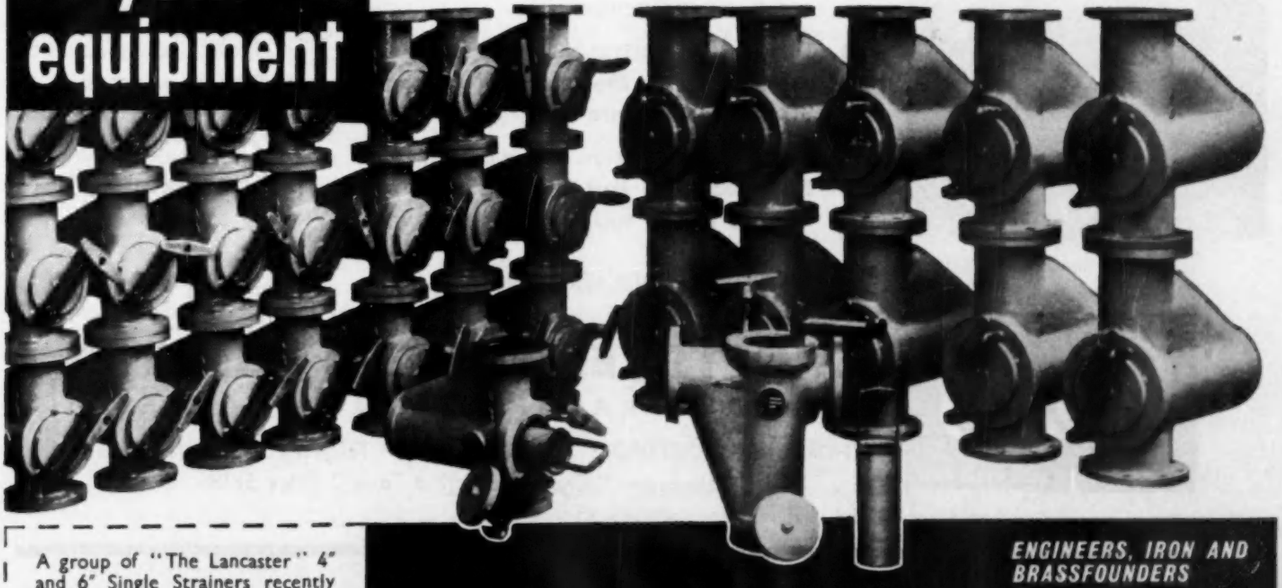

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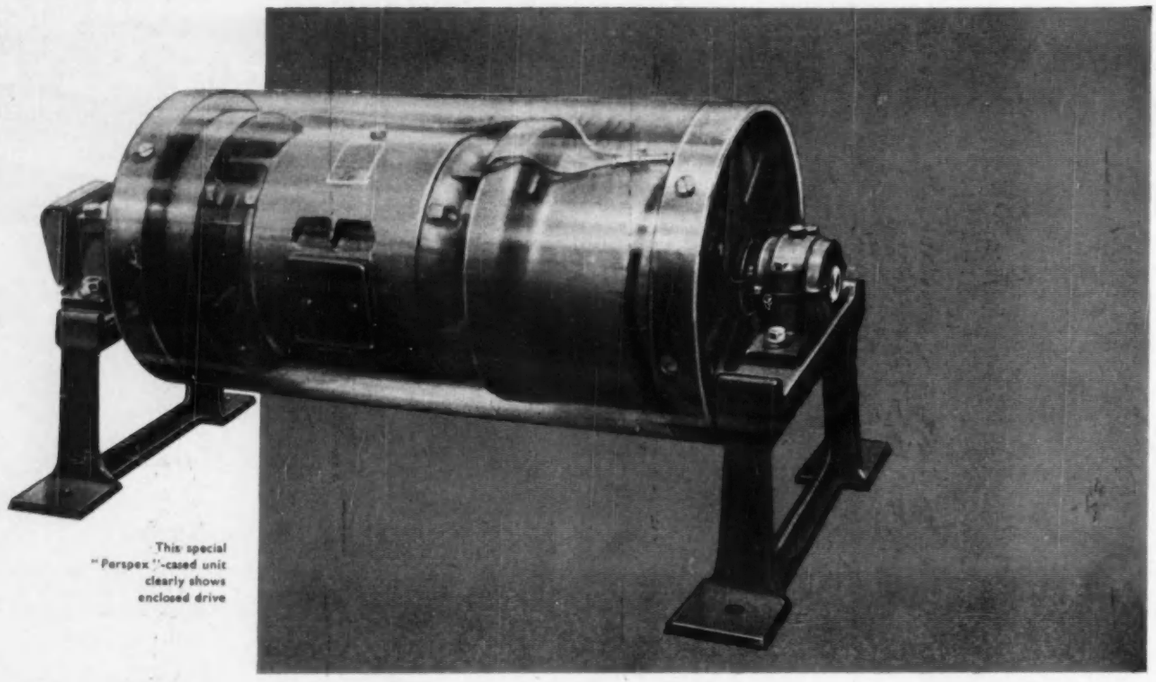

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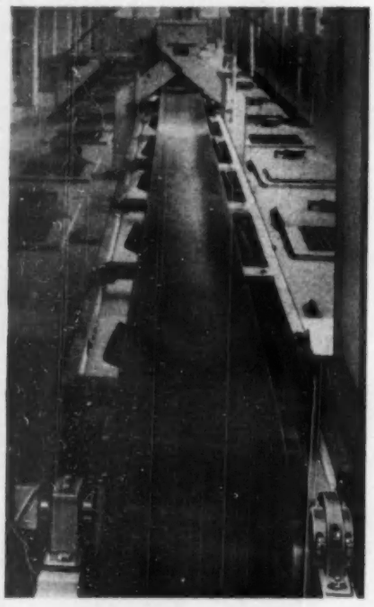

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# THE ENGINEER

No. 5475 DECEMBER 30, 1960 Vol. 210

## TRANSPORT REORGANISATION

According to orthodox socialist thinking, at the time when the British Transport Commission was set up, all forms of transport had to be under a single authority in order to ensure co-ordination and the most economic use of each form. But the idea failed to work. For factors such as speed, punctuality, freedom from breakages, &c., and, especially, convenience, are just as important in transport, as is cost; and from the very beginning the Commission proved ill able to compete with "C" licensees on the roads. Now the whole idea of co-ordination by a central body is to be abandoned. Under the terms of a White Paper, from which we print excerpts on page 1079, the Commission is to be broken up. Each of the varied businesses for which the Commission is at present responsible is to become a separate entity. There are to be independent boards controlling London Transport and British Transport Docks, and an independent Authority for Inland Waterways, and a new holding company will take over the control of a number of undertakings all already in company form (except hotels) concerned with road haulage, road passenger transport, hotels and travel services. A further step is to be taken towards giving more nearly complete autonomy to the railway regional boards. But there is to be a British Railways Board which apparently will have control of many of the purse strings and which will be concerned with the fixing of wage rates and the overall control of finance, investment, and research, and "the determination of the future size and shape of the railways". In fact, instead of that co-ordination of road, rail and canal services which socialists sought, competition is to rule. Such co-ordination as remains is to be the responsibility of the Minister of Transport, who will be advised by a new Nationalised Transport Advisory Council with no executive powers.

The enterprises now to be hived off from the administration of the railways have proved capable of profitable operation and can be expected to continue to prosper. Their capital value is assessed at £400 million. But the railways, which are financially in dire straits, need to be, and are to be, financially assisted. Effectively railway capital is to be written down from some £1,600 million, of which £400 million is attributable to accumulated losses, to £400 million. Of the remaining £1,200 million £400 million is to be written off as irrecoverable — the taxpayer will never get that money back. Another £800 million is to be converted into something rather like "ordinary" stock; only if railway finances improve sufficiently will any interest be paid on it or will any of it be repaid. In this way the railways will be relieved of the payment of £40,000,000 of annual interest (for which the taxpayer becomes liable) and they are also to be relieved of remaining restrictions upon their commercial freedom so as to improve their competitive power. Though the London Transport Board, still, despite the competition of private cars, mopeds, &c., regarded as a monopoly, is to remain under statutory control upon its charges, the railways as a whole are to be made free to vary freight charges and passenger fares as and when they feel it necessary. Additionally, statutory restrictions on the development of railway property are to be "relaxed" whatever that may mean; and the conditions under the terms of a number of Acts whereby coastal shipping has some protection against the competition of inland transport are to be "examined". The railways are to have power to "lease, provide and operate pipelines on their property".

What does it all add up to? One sentence in the White Paper reads, "A railway system of the right size is an essential element in our transport network and will remain so as long as can be foreseen." We protest again as we have protested before that no service is done to the railways by such insistence upon the untruth that railways are essential to this country, though they once were. If railways are to survive through the next twenty-five years, during which motorways will be extended over the whole country and possibly into the hearts of cities as well, they will have to prove themselves capable of competing in convenience as well as cost for the carriage of freight and passengers. It will be no easy task; for at present they run annually short by about £60,000,000 of covering their running costs. Under the terms of this White Paper the railways will be finally stripped of every encumbrance to their power to compete. Two sentences from the Paper express much better than that already quoted what the position is to be. "The practical test for the railways, as for other transport, is how far the users are prepared to pay economic prices for the services provided. Broadly, this will in the end settle the size and pattern of the railway system." One can easily see that if, despite modernisation, the railways prove unable to compete, that shrinkage of railway route mileage, which has already begun as uneconomic lines are closed down, will continue until, perhaps, not even a "rump" remains. The Railway Conversion League would rule triumphant as the railways would be converted, no doubt, into roads. A revival of regional loyalties and of regional autonomy may go far to help towards success. We wonder also whether, particularly on the managerial side, the infusion of some fresh blood, half promised in the White Paper, might not do good in the cold-blooded assessment of modernisation finance and help towards the introduction of time-saving and labour-saving methods of handling goods and passengers. But above all there needs to be spread among railwaymen the exciting realisation that they are engaged not in an exercise

in the modernisation of an essential service which the nation cannot afford to lose, but in a real fight for existence. The choice before them is to see the railways they serve die a lingering death or, gloriously, to revive their fortunes. Which will it be?

## A GREAT INDISPERSIBLE CLOT

This "leader" is about roads — the roads that do not exist, nor have yet even been drawn on paper, to serve the metropolitan area of London. The subject is a familiar one in these columns, and has been commented upon several times in the past twelve months, either in general discussion of the modern city and the motor vehicle, or more specifically in discussing the special difficulties of London. We return to the subject once more because, on December 9, the British Road Federation's counsel, Mr. Blain, presented objections to the L.C.C.'s revised development plan at a court of inquiry under an inspector of the Ministry of Housing and Local Government. The objections were based on the view that the revised development plan "failed utterly to show any constructive policy at all" as regards highways. Mr. Blain asserted that the limitations which the revised plan not only accepted but imposed would make London "the great indispersible clot in the nation's main arteries and the great impediment to the flow of its life-blood". A proper plan for London could not be devised, unless based on a realistic highway system, he went on. Some of the principal points of Mr. Blain's case were as follows. The L.C.C. accepted that their proposals were not commensurate with the needs. Urban motorways were needed, and he had been unable to find expert refutation of any one of the advantages claimed for them. The best interests of Londoners would be served if the revised plan set out an imaginative road programme, and presented evidence why it was essential. The Nugent committee had said that it was not possible for financial and practical reasons to include motorways in its programme. Mr. Blain commented "if ever there was a defeatist policy accepted by tiny minds, that is it".

Counsel for the L.C.C., Mr. K. Goodfellow, replied. He asserted that all the road improvements in the revised plan were essential, and would be essential if a scheme of motorways were provided in addition. In fact the L.C.C. accepted the motorway concept, but "felt it would be impossible as a local planning authority to include in the Statutory Development Plan indications of motorway proposals which, against the national financial background, it had no kind of assurance that it would be in a position to put into effect at all, let alone in the number of years for which the plan was prepared". There was a need for a detailed survey of traffic movement and of traffic volumes, necessary as an essential prerequisite of the intelligent planning of any motorway system for London, and no such detailed survey had yet been undertaken. The economic justification of motorways, said Mr. Goodfellow, was in one sense based on a total unreality. It might well be that savings to the community would result, but it was quite wrong, he asserted, to talk about an amount of money spent on roads as being a bargain in relation to the kind of figure put upon the economic loss occasioned by the present system. Whoever had to pay for the roads did not get, as his return, the kind of figure which had been assessed as the amount of the economic loss. Mr. Goodfellow referred to the damaging and unfair consequence of putting into development plans long-term and generalised proposals which had no real assurance of implementation. Unless specifically directed by the Minister of Housing, the L.C.C. would not feel it right to put into the review broad proposals for a motorway in London against the background of the present situation of financial grants.

We have every sympathy with the British Road Federation in its broad aim of securing a reasonable highway system in London. It may well be that present forms of administration are unsuited to tackling the problem: they increase the ease with which responsibility for action can be dodged, or for inaction justified. But the plain fact is that no great city can adequately plan its development unless its plan is conceived around a skeleton of basic services of various kinds, of which one in London — the road system — is obsolescent. The lack of a proper road programme in London not only condemns it to an endless future of traffic congestion, but unbalances the whole concept of planned development, impeding alike the mobility and convenience of its inhabitants, the imaginative talents of its architects and planners, and the initiative and prosperity of its developers. The Federation's ultimate assertion emerged, in our view, unscathed from the day's argument, namely "that the Council should be directed forthwith to embark upon a true constructive road policy, because that was an even more important matter than any other proposals in the Plan. The Minister, in whatever way he regarded as the appropropriate method, must ensure that some such constructive road policy was undertaken."

## The Engineer—100 Years Ago (DECEMBER 28, 1860)

"The Electrical Telegraph at Oldham"

"A line of telegraph, of somewhat novel construction, has just been completed for Messrs. Platt Brothers and Co., the extensive machinists of Oldham. The two great branches of this establishment, where upwards of 5000 workpeople are employed, are about a mile and a half from each other on opposite sides of the town, which is now bridged over by the electric telegraph. The wire, which is of steel, and about two-tenths of an inch in diameter, is supported for its entire length near the summit of six tall factory chimneys at an elevation of 180ft from the ground, and leaving clear spans of 1000ft to more than 2000ft between the supports. The lowest points of the curves ranging from 70ft to 120ft above the surface of the ground. To a spectator placed at the extremity of the curve formed by the longer lengths the wire appears to stretch out like a thread which vanishes in the mist long before the eye reaches the other. The chimneys to which the telegraph is fixed being always at work, and consequently very dry, renders insulation almost unnecessary. Access to the tops of the shafts being gained by the means of ropes drawn over with a kite string. The works were projected and carried out by Mr. H. Wilde, of Manchester."

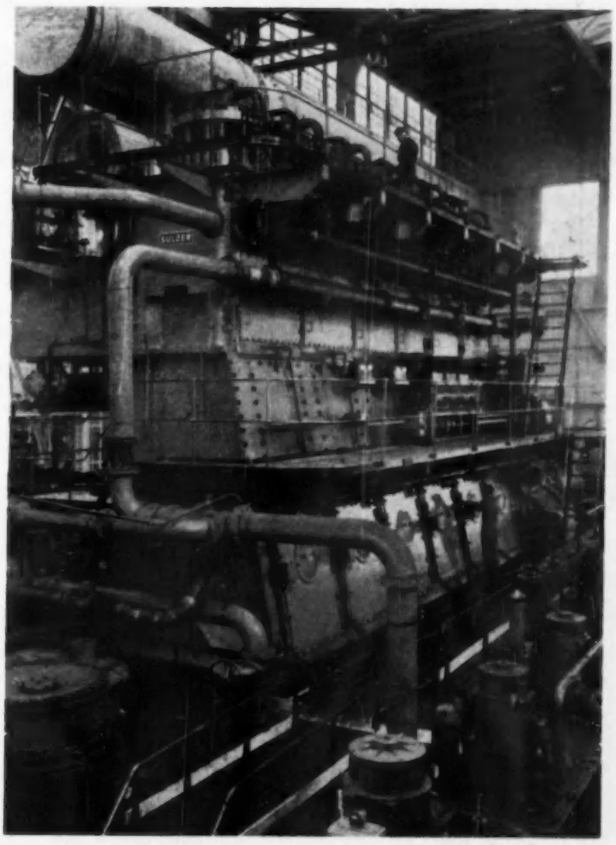
# Large Bore Marine Diesel Engine

*The trend in ships towards greater deadweight capacity and higher speeds has called for machinery of considerably higher powers. To meet this demand Sulzer Brothers, Ltd., has extended the range of its mark " RD " engines to include a unit having a bore of 900mm. This is conservatively rated to develop 2000 b.h.p. per cylinder at 119 r.p.m. with a brake mean effective pressure of 108·8 lb per square inch to provide a power range up to 24,000 b.h.p.*

FOR some time Sulzer Brothers, Ltd., of Winterthur, Switzerland, has been engaged on the problem of developing diesel engines of greater output in order to widen the potential field of application and compete in the power range which has been hitherto a monopoly of the steam turbine. Apart from being concerned with raising the output of power the company has been engaged in the question of producing a series of engines to provide adequately for a wide range of possible power demands. Detail design of components has received close attention to improve engine efficiency and simplify construction while the overall design and the various engine systems have been examined to effect improvements in the light of the experience gained with earlier and current marks of Sulzer engines. These various investigations resulted, following the success of the R.S.A.D. engines, in the evolution of the company's mark " RD " engine which has maintained the standard of operational reliability and long service life of previous marks of engines while giving a higher specific output. This was achieved by completely dispensing with the scavenge pumps and by adopting turbo-charging as standard for the engine, so that the saving in weight and economy of space associated with the turbo-charging of two-stroke engines was embodied in the engine, while further saving was effected by economical design and planned siting of components.

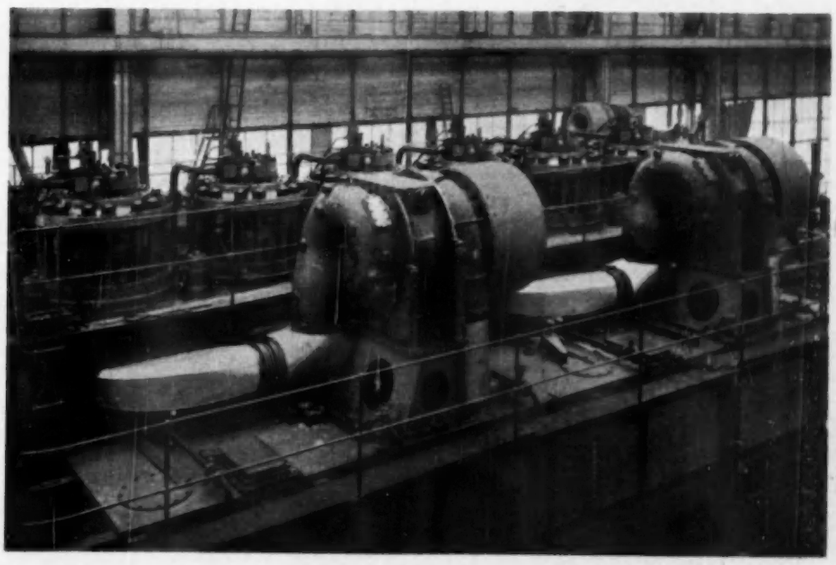
To provide wide coverage of horsepowers the " RD " range has now four sizes of bore namely ; 560mm bore by 1000mm stroke, 680mm bore by 1250mm stroke, 760mm bore by 1550mm stroke and 900mm bore by 1550mm stroke. The initial ratings of the engines are as follows : RD.56 at 750 b.h.p. per cylinder at 170 r.p.m. ; RD.68 at 1100 b.h.p. per cylinder at 135 r.p.m. ; RD.76 at 1500 b.h.p. per cylinder at 119 r.p.m. and RD.90 at 2000 b.h.p. per cylinder at 119 r.p.m. All these engines are available with five to twelve cylinders except the RD.90 which has six to twelve cylinders, and the horsepower ranges of the various marks are respectively ; 3750 b.h.p. to 9000 b.h.p., 5500 b.h.p. to 13,200 b.h.p., 7500 b.h.p. to 18,000 b.h.p., and 12,000 b.h.p. to 24,000 b.h.p. These engines, which follow the long line dating from 1910, when Sulzer Brothers started to build valveless two-stroke marine diesel engines, are reversible, single-acting, turbo-charged, two-stroke units having direct fuel injection. They are intended to power single screw ships and to be direct coupled to the propeller and the larger marks of engine stem from the need, well recognised at Winterthur, to design and build engines to give the higher power outputs required to propel the cargo ships and oil tankers of large deadweight which reflect the trend in present-day shipbuilding. These engines are built to ensure high operational reliability and long service life coupled with low cost and economical running, low weight and modest demands on space.

Since the introduction of the RD.76 engine two years ago over a hundred of these units have been ordered and many are in service and the " RD " range has been extended to include lower and higher ratings. The engine having the higher rating is the mark RD.90 of which we recently inspected a six-cylinder unit on the test bed at Winterthur and which is indicative of the progress made in the fifty years since the first directly reversible two-stroke engine was built at Winterthur and which had a bore and stroke of 175mm by 250mm and had an output of 22·5 b.h.p. per cylinder at 375 r.p.m. About sixteen RD.90 engines are already on order, including eight in Japan, five at Winterthur and an eight-cylinder unit under construction by Hawthorn Leslie (Engineers), Ltd., for a tanker building for B.P. Tanker Company, Ltd. In keeping with the endeavour to attain a high b.h.p./weight ratio the engine weight ranges from 510 metric tons for six cylinders to 960 metric tons for twelve cylinders, the



**Fuel pump side of " 6RD.90 " marine diesel engine**

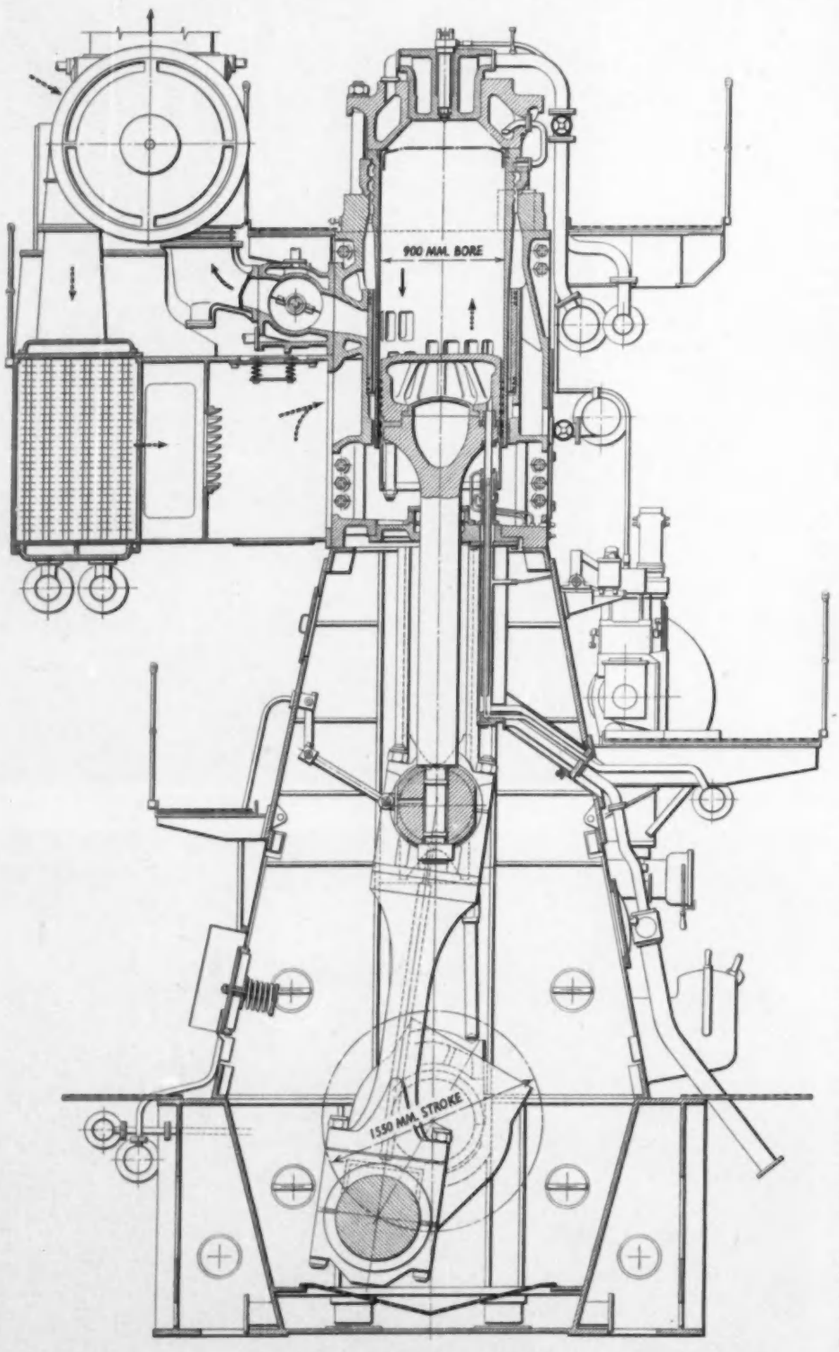
**Exhaust-gas turbo chargers**



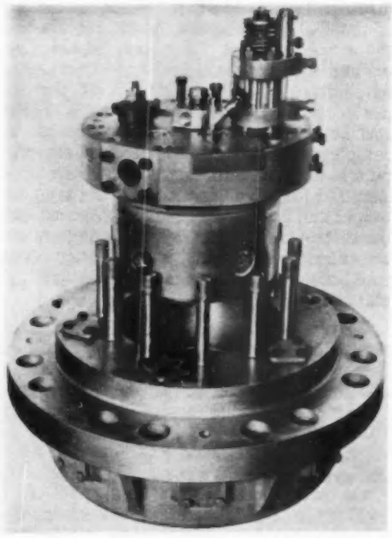
cylinder spacing being 1680mm and the respective lengths being 13,160 metres and 24,210 metres. This latest increase in size of cylinder is not the first occasion on which the company has built engines of this bore, since three five-cylinder units were completed in 1929 and a single-cylinder experimental engine of 1000mm bore was on test before the first world war and developed 2000 b.h.p. at 150 r.p.m.

The engine, presently on the test bed, of which we include a view of the fuel pump side, and also a cross sectional drawing, is equipped with two turbo-blowers, which can be seen in our illustration, mounted on the air receiver. The blowers operate on the pulse system and are independent of the crankshaft, their speed varying automatically with the engine load, and they are lubricated through filters from the engine system. No auxiliary drive or blower is required for starting or for operation at partial loading, and the blowers discharge through coolers into the scavenging air receiver and through non-return valves into the chambers below each cylinder. Here the air is further compressed during the downward stroke of the pistons before entering the combustion space on the scavenge ports being uncovered. The volume of air displaced by the underside of the piston is adequate both to scavenge and charge the cylinders when starting up and indeed the engine will continue to run with the blowers out of action although at reduced efficiency and speed. With the cylinder full of fresh air, fuel consumption is improved and the exhaust remains clear even down to low loads. The engine rating of 2000 b.h.p. per cylinder with a brake mean effective pressure of 108·8 lb per square inch represents a very conservative rating and the builders are quite confident that the engine, with suitable adjustments of turbo-chargers and fuel injection equipment, can be run at 150 lb per square inch b.m.e.p. to develop 2800 b.h.p. per cylinder. However this is an objective to be attained after sufficient experience has been gained of engine operation at the higher pressures.

Our sectional elevation of the engine shows the arrangement of blowers and scavenge air receiver and the rotary exhaust valve which has flexible edges and cannot jam. It will also be noted that the fuel pumps are at a point half up the engine; this has simplified the drive but has increased the length of fuel delivery pipe; however, this has had no adverse effects. The pumps are fitted in pairs and each cylinder is fed by a separate fuel pump barrel and the injection timing remains unchanged for ahead and astern running owing to the oil operated reversing servo-motor. Fuel quantities are under the control of a Woodward hydraulic governor and the engine is controlled by a single lever which is interlocked with the ship's telegraph. The bedplate is self-supporting and of welded box construction with a completely closed base, forming an oil sump. Special transverse members serve as anchors for the tie rods which connect the bedplate, columns and cylinders and are pre-tensioned in order to absorb combustion and inertia stresses. The columns, also of welded design, are double walled and rigidly interconnected, while the individual cylinders, in grey cast iron, are bolted rigidly together to form one stiff block.




Sectional elevation of "RD.90" engine

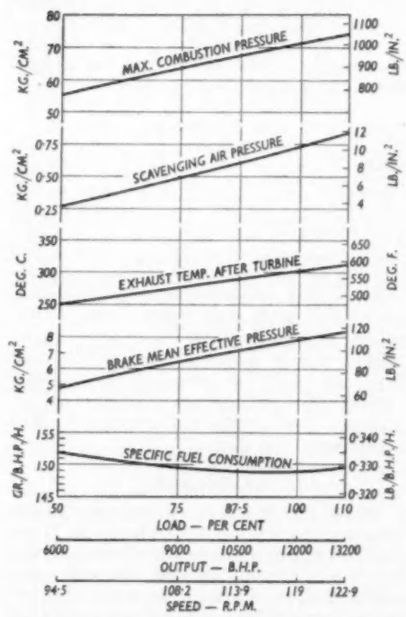


Cylinder cover

The liners of vanadium-titanium cast iron are fine turned on the inside face and not honed and are double walled at exhaust ports which are kept clean by the degree of cooling at these points. The pistons have cast steel crowns which have internal ribs and cast iron skirts and five rings with two copper lead guide rings, and are fitted to forged piston rods which pass through stuffing boxes separating the cylinders from the crankcase. Twin guides, fore and aft, are separately bolted to the columns and the symmetrical crosshead with its shoes gives the same reliability ahead and astern. The crankshaft, of 44 tons to 50 tons per square inch Siemens-Martin steel,

is of semi-built design and is not drilled for lubrication purposes, the lubricating system employed making this unnecessary, and is carried in steel backed white metal lined bearings. The cylinder head illustrated herewith is in two parts, the outer being of cast steel and the insert being of cast iron and having four bores to take fuel, starting air, relief and indicator valves. Starting air is delivered at 250 atmospheres and the fuel valve lifts at 250 atmospheres with the peak pressure being about 600 atmospheres, while the relief valve is set at 90 atmospheres.

The engine is pressure lubricated, the oil pressure being 5 atmospheres at the pump, 3·5 atmospheres at the crosshead and 2 atmospheres at the main bearings. There are eight lubricating points in the cylinder liners the oil being delivered through rustless steel quills, and the supply being controlled by output.




**Performance test results of "6RD.90" engine**

Test results of the 6RD.90 engine are shown graphically and indicate that the engine develops 2000 b.h.p. per cylinder at 119 r.p.m. with a brake mean effective pressure of 108·8 lb per square inch, the mean indicated pressure being 120 lb per square inch, a maximum combustion pressure of 1000 lb per square inch and a fuel consumption of 0·328 lb/b.h.p./hour. At 110 per cent load the output per cylinder is 2200 b.h.p. at 123 r.p.m., the brake mean effective pressure being 116·4 lb per square inch and the mean indicated pressure 129·2 lb per square inch. Based on an aspirated engine having a brake mean effective pressure of 76·6 lb per square inch the percentage of boost is 44. The following figures were recorded during the first test at Winterthur.

| | |
|---|---|
| Room temperature | 72 deg. Fah. |
| Temperature after blower and before cooler | 185 deg. Fah. |
| Air temperature after cooler | 93 deg. Fah. |
| Charging air pressure | 10·6 lb per square inch |
| Total air flow per cylinder | 9 lb per second |
| Exhaust gas temperature before turbine | 735 deg. Fah. |
| Temperature after turbine | 563 deg. Fah. |
| Exhaust gas per cylinder | 9·2 lb per second |

The engine is designed to run on heavy fuel, up to 4000 sec. to 5000 sec. Redwood, in service and weighs, including water and oil, 502 tons which equals about 24 b.h.p. per ton or 93·5 lb per b.h.p. The length overall is 43ft 2in, the maximum width is 16ft 11in and the maximum height is 31ft 5in.

# Reorganisation of the Nationalised Transport Undertakings*

## The Government's Aim

THE Government's aim is that the nationalised transport undertakings shall be soundly based both in organisation and finance, providing efficient services to industry and the public, and giving a good livelihood and worthwhile jobs to those who work in them.

There is much to do and a long way to go. By the end of 1960 the deficits of the British Transport Commission will have reached a total of about £500 million ; the rate of annual deficit is now about £100 million.

Sweeping changes will be needed. Effort and sacrifices will be required from all. The public will have to be prepared to face changes in the extent and nature of the services provided and, when necessary, in the prices charged for them. The taxpayer will have to face a major capital reorganisation as well as continue to carry a large part of the burden until the railways are paying their way again. Those working in these undertakings, if their livelihood is to be assured, will have to play their part in increasing productivity and enabling the labour force to be deployed so as to secure maximum efficiency in operation. When the Government made funds available to implement the Guillebaud Report last Spring they made it clear that far reaching changes would be necessary.

## The Problem

The heart of the problem is in the railways. They are a great national enterprise and a vital basic industry. They employ 500,000 people and represent an investment of nearly £1600 million which is growing by more than £100 million each year. A railway system of the right size is an essential element in our transport net-work and will remain so for as long as can be foreseen. The development of other forms of transport and new techniques have faced British Railways, like the railways in other countries, with problems of competition and adaptation to modern circumstances and public demand.

The railways are now in a grave financial plight. They are a long way short (by about £60,000,000 a year) of covering even their running costs. This is quite apart from the problem of meeting their interest charges, whether upon the price paid for the undertakings or upon the money since borrowed for modernisation and other purposes. These interest charges now total some £75,000,000 a year†.

The practical test for the railways, as for other transport, is how far the users are prepared to pay economic prices for the services provided. Broadly, this will in the end settle the size and pattern of the railway system. It is already clear that the system must be made more compact. There must also be modernisation, not only of lay-out, equipment and operating methods, but of organisation and management structure.

The answers to these problems will not be found overnight, but the Government are convinced that as an essential first step there must be radical changes in the organisation, financial structure and statutory framework of the undertakings controlled by the British Transport Commission.

## The Government's Main Conclusions

The activities of the British Transport Commission as at present constituted are so large and so diverse that it is virtually impossible to run them effectively as a single undertaking. The size and difficulties of British Railways have understandably tended to preoccupy the Commission and have undoubtedly affected its outlook over the whole range of its activities. This has been particularly apparent in financial and commercial matters, in the consideration of which there has been a tendency for technical and operating factors to prevail over others. There has also been, as the Select Committee point out in paragraph 417 of their Report, a "confusion in judging between what is economically right and what is socially desirable."

The commercial capability of the railways is circumscribed by outmoded statutory obligations and restrictions on their trading operations.

Mounting deficits, the size of capital debt in relation to the earning capacity of the assets and the increasing burden of interest as modernisation proceeds, present a situation detrimental to the morale of management and workers, to financial control, and to hopes of recovery.

In these circumstances, the Government have decided :

(*a*) To replace the British Transport Commission and the existing organisation by a new structure designed to overcome the main defects and disadvantages of the present organisation.

(*b*) To reconstruct the finances of the Commission and, in particular, those of the railways.

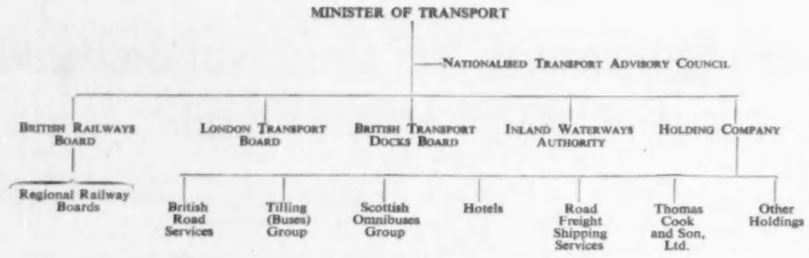
(*c*) To give the various undertakings the maximum practicable freedom of operation in their commercial affairs.

## A New Structure

The Government propose that each of the main activities of the present Transport Commission should be managed by a separate Board holding its own assets and responsible for its own capital debt. This should lead to concentration of effort and to devolution and definition of responsibility, and thus secure more effective management and foster financial discipline. The object is to provide each Board and management with a clearly defined task within a set field. The administration of such diverse activities as British Railways, Ports, Waterways, and London Transport, presents special problems, each of which calls for particular qualifications and experience. The Boards for British Railways, London Transport, British Transport Docks and British Waterways will each be incorporated under statute with the appropriate duties and powers necessary to the efficient conduct of those undertakings. In view of their importance and the special nature of their problems they will be responsible direct to the Minister of Transport, who will appoint their members. All the other activities will be grouped under a Holding Company. A chart showing the new structure is reproduced on the next page.

* Excerpt from a White Paper under this title presented to Parliament on December 20, 1960.

† The figures in this paragraph relate to railways alone. They make no allowance for surpluses, at present some £10,000,000 a year after meeting interest charges, arising from the other activities of the Commission.




**The new structure**

### BRITISH RAILWAYS

*The British Railways Board.*—The British Railways Board will assume the responsibility for running the railways as an effective national system and will be vested with the railway assets (including the railway workshops) and the responsibility for the capital debt of the railways as a whole. The Board will, however, perform only those central functions which are essential to the running of the railways as a single entity ; all other functions will be the responsibility of Regional Railway Boards. Notably, the British Railways Board will be responsible for such matters as national staff and wage negotiations, overall control over finance and investment, policies for safety, training and research, and the determination of the future size and shape of the railway system.

The Railways Board will be composed of a chairman and vice-chairman ; a representative from each of the Regional Railway Boards ; certain full-time members with special responsibilities, and one or two part-time members.

*Regional Railway Boards.*—The Regional Railway Boards, which will replace the present Area Boards, will be fully responsible for the management and operation of their regional railway systems. Each will be autonomous in all matters which concern its region alone. They will thus continue the process of devolution of authority and decentralisation of management. Each Regional Railway Board will maintain a regional trading account as a means of assisting it to secure the highest level of efficiency and economy of operation. (The Commission's consultants have suggested possible bases for such accounts and their report is under consideration.) The members of the Boards will be few in number and there will be a strong element of full time members. The post of Regional General Manager will carry a seat on the Regional Board.

To secure co-ordination between national railway policy and regional railway operation one representative from each of the Regional Railway Boards will be a member of the British Railways Board.

*Packet Ports and Shipping Services.*—The packet ports and those shipping services which are extensions of the railway system will continue to be treated as part of the railway system.

### LONDON TRANSPORT

The London Transport Executive will be called the London Transport Board and will continue to be composed mainly of full-time members of whom a number will have special responsibilities. It will be responsible for the public transport monopoly at present delegated to the London Transport Executive. As hitherto, it will work in close concert with the London lines of British Railways in all matters of common concern.

### BRITISH TRANSPORT DOCKS

The ports and docks at present administered by the Commission's British Transport Docks Division will be transferred to a new statutory Docks Board. The Board will be small in number. Its composition will reflect those functions, including finance, which require to be dealt with centrally. The management of the more important of its ports will be represented on the Board.

### INLAND WATERWAYS

British Transport Waterways will be placed under an independent statutory Board to be known as the Inland Waterways Authority. This body will own and manage the nationalised inland waterway system. It will also be responsible for proceeding with the redevelopment or disposal of waterways which no longer have a transport use. The composition, powers and duties of the new body will require further discussion. It will be necessary to take account, on the one hand, of the charge which the waterways system imposes on public funds, and, on the other, of the varied purposes which they can be made to serve.

### THE HOLDING COMPANY

British Road Services, the Tilling (Buses) Group, the Scottish Omnibuses Group, British Transport Hotels‡ Road Freight Shipping Services, and Thomas Cook and Son, Ltd., will each be operated as companies incorporated under the Companies Act with their own Boards.

All these undertakings (except the hotels) are already in company form. They all operate in the same general field as private enterprise, with which they are often in competition. They will all, including the hotels, now be grouped under a new Holding Company responsible to the Minister, who will appoint its Board.

The Commission's present minority shareholdings in certain transport concerns will be transferred to the Holding Company. On the other hand, there are certain companies either controlled by the Commission or in which the Commission hold a minority interest, the activities of which are essentially connected with the railways. The Commission's holdings in these companies will be transferred to the British Railways Board.

### FREEHOLD AND LEASEHOLD PROPERTY

The development of the valuable properties at present held by the Commission is a matter requiring special attention. It is proposed to set up one or more organisations specially equipped to advise the Statutory Boards and the Companies and act for them as necessary, with the object of obtaining the best possible return, in connection with the development of their property, and the transfer or disposal, from time to time, of such of it as is no longer required for operational purposes.

### CO-ORDINATION

Co-ordination of policy between the new Boards, including allocation of funds for new investment, will be the responsibility of the Minister of Transport. In this he will be assisted by a new advisory body, the Nationalised Transport Advisory Council. Suitable arrangements will also be established for co-ordinating the day-to-day activities of individual undertakings, including the co-ordination of road and rail services.

The new organisation is intended to provide for direct contact between the Minister and the main component parts of the nationalised transport industry. Nevertheless the Government do not propose that the Minister's existing statutory powers and responsibilities in relation to the nationalised transport undertakings should be extended. As in the case of other nationalised industries, the Minister's main charge will be for overall co-ordination and for securing the general efficiency of the undertakings in accordance with his responsibility to Parliament for them. He will continue to discharge these responsibilities through his powers of appointment and of general direction and his control of development, investment and finance. His special duties in respect of safety, training and research will continue.

### NATIONALISED TRANSPORT ADVISORY COUNCIL

The Nationalised Transport Advisory Council's main responsibility will be to advise the Minister on questions relating to the co-ordination of the nationalised transport undertakings and on questions of policy. The Council will have no executive functions. It will consist of the chairmen of the Boards of British Railways, London Transport, British Transport Docks, the Inland Waterways Authority and the Holding Company. Other members will be added, drawn from outside the nationalised transport undertakings. The Minister will ordinarily act as Chairman of the Council.

### APPOINTMENTS

The chairmen of the five major Boards will be appointed by the Minister of Transport. The members of each of these Boards will be appointed by the Minister after consultation with the chairman. Certain other appointments will be subject to the Minister's approval. The Government consider it important that, so far as possible, the nationalised transport undertakings should produce their own leaders. Promotion from within the undertakings to the highest levels should be within the grasp of those who prove themselves capable. In particular, there should be much greater opportunities in future for those in all parts of the railway service to make their way to the top. At the outset, however, some major posts may have to be filled from outside.

The remainder of the White Paper is concerned principally with finance. Effectively there is to be a writing down of the railways' capital liabilities from £1600 million to £400,000,000. A sum of £800,000,000 "will be placed to suspense account and carry neither fixed interest nor fixed repayment obligations. The amount and treatment of this account will be subject to review from time to time, in the light of developments and in particular of an examination which will have to be made of the book value of assets acquired up to and including 1955. Amounts may well have to be written off in respect of ascertained capital losses (including losses in respect of assets which become obsolete as modernisation proceeds). The existence of the suspense account, however, will enable the Exchequer to obtain some return if railway finances improve sufficiently."

It is also proposed to free the railways of remaining commercial restrictions.

‡ Railway catering services will be the responsibility of the railways.

# Machine Tool Research, Design and Utilisation

By D. F. GALLOWAY, B.Sc. (Eng.), Ph.D., Wh.Sch.*

*For the James Clayton Lecture presented to the Institution of Mechanical Engineers on Wednesday, December 14, Dr. Galloway gave a survey of the wide field of machine tool research, design and utilisation. He dealt in some detail with the many problems involved in designing machine tools and gave a number of recommendations as to the lines which should be followed to provide industry with the best means of production. A number of the points of interest in the lecture are included in the abstracts we reproduce.*

MACHINE tools are in a very real sense a key to modern industrial progress and modern standards of living. The machine tool of to-day is often designed to transcend the mental and physical resources of human operators and to eliminate the errors and limitations imposed by human fallibility and fatigue. Modern machine tools are therefore complex mechanisms. Nevertheless they are required to work with consistent precision and efficiency for long periods over a wide range of speeds and working conditions, and to manufacture products in a considerable variety of sizes, shapes, and materials.

Thus machine tool research and development also tend to be complex, and inevitably involve the identification and consideration of a large number of factors and criteria relevant to the machines themselves and to their utilisation as manufacturing units converting raw materials into finished products.

## Criteria of Machine Tool Performance

The selection of a machine tool should be based on the overall efficiency and economy of the service it will render to the manufacturing unit. For this reason the final basis for selection is an *economic* basis and it follows that the yardstick for decisions on design, development and utilisation must also be an *economic* yardstick. This means that practical research must be related to the economic requirements of machine tool users, and must feed to machine tool designers the type of information which will enable them to satisfy users' requirements.

The determination of these economic requirements of machine tool users and the evaluation of economic performances of the machines are often based on *qualitative* assessments. Consequently, a useful contribution of machine tool research is to establish *quantitative* methods of assessment so that the economics of different machines and schemes of utilisation can be assessed with reasonable accuracy on a factual basis, independent of personal opinion and conjecture. In practice this involves the identification of various technical criteria which facilitate the measurement of the overall economy of machining operations.

It follows that a prime object of machine tool research is to identify the factors which influence these measurable criteria of overall economy and then to discover the nature and magnitude of the effect of these factors on the criteria and thus on manufacturing economy. Charts of such factors and criteria are an obvious starting point for machine tool research. Many of the factors and criteria are common for different types of operation and machine, but their significance varies. For example, considerations of accuracy and stability are different for precision grinding machines from those for radial drilling machines.

Modern science is continually providing new facilities for the identification, measurement, and control of the factors and criteria associated with machine tool performance and this gives increasing scope for comprehensive mathematical treatment of the machine tool and cutting tool behaviour. Thus fundamental theoretical analyses can be used to indicate targets for machine tool performance, and actual performance can then be compared on a realistic basis with theoretical performance.

## Terminology and Specification for Machine Tools

As in many other branches of engineering, particularly in the related field of cutting tools, machine tool engineering is beset by problems of inadequate and inconsistent terminology and specification. In particular the establishment of more clearly defined limits of accuracy, alignment, vibration, efficiencies, &c., would advance machine-tool technology very considerably, not only for the benefit of the great body of machine tool users, but also for the machine tool industry itself.

Some recent researches have thrown considerable light on more adequate specification of machine tools than is common either in existing standards or in the practice of the machine tool industry to-day. The charts issued jointly by the Institution of Mechanical Engineers and the Institution of Production Engineers between 1940 and 1948 were a useful beginning, but experience and research in recent years show that these charts now need considerable modification and extension. The preparation of revised tests and tolerances is a co-operative enterprise involving machine tool makers, users of machines, and research and standardising organisations. Extensions to the accuracy and alignment charts of the Institution of Mechanical Engineers and Institution of Production Engineers might well include data on vibration characteristics, metal removal rates, workpiece surface finish, &c. At the present time machine tool specifications contain practically no quantitative data on deflection and vibration characteristics, which vitally affect efficient operation.

Because the accuracy and alignment of machine tool movements and of certain elements such as table spindles directly affect the accuracy of the products, it is essential that appropriate levels of accuracy and alignment should be maintained throughout the life of the machine and under full range of working conditions. The establishment of an agreed basis for accuracy and alignment tests is now a practicable objective in the light of extensive research and testing carried out in the past ten years. The existence of recognised performance standards would materially assist in the selection of machine tools and also in establishing a basis for reconditioning machine tools, particularly in the planned maintenance programmes now increasingly used in the engineering industry.

## Machine Tool Deflection

Modern trends towards faster rates of metal removal, greater accuracy, and higher surface finish have emphasised the necessity for increased static and dynamic stiffness of machine tool structure. In finish-machining the rate of elimination of initial errors of the work and the generation of final accuracy are largely governed by the static stiffness of the machine and workpiece set-up. Full utilisation of the machine capacity with freedom from excessive vibrations during rough machining is dependent on the dynamic stiffness and resulting vibration characteristics of the machine. For many years quantitative data on the deflection of machine tools under working conditions was very limited, but recently, extensive experiments on a wide range of machines, both British and foreign, have given a comprehensive picture of machine distortions and vibrations under working conditions, and have revealed a number of common weaknesses which can be remedied.

In practice flexural movements of machine tool elements often have to be dealt with in conjunction with other movements resulting from the accumulation of minute degrees of slackness in bearings, slides, &c. Simple tests of the resultant deflections of machine tools under loads such as may be imposed by the action of tools, workpieces, gearing, &c., are not nearly as common as accuracy and alignment tests. However, they are such an obvious extension of the usual "no load" accuracy and alignment tests, and are so simple in concept and easy to execute, that there is no doubt that their wider use would benefit makers and users alike.

## Vibration of Machine Tools

Vibration is another important part of the physical behaviour of machine tools and a factor affecting the quality and economy of operation of each machine as a manufacturing unit.

The measurement and analysis of vibrations have now become powerful aids to improved design and utilisation of machines, and some of the more common vibration parameters could with advantage be incorporated in standard machine tool test procedures. Such tests could supplement or replace some deflection tests since techniques of plotting vibrating shapes can sometimes show structural weaknesses which would be difficult to detect by common methods of static loading.

A wider understanding of vibration tests and techniques and practical implementation of experimental results would lead to significant improvements in machine tool design and more effective inspection tests. The determination of suitable parameters which, when related to types of machine and working conditions, will form a reliable guide to the limits likely to be imposed by vibrations on machine utilisation is one important object of vibration research. This aspect of discrimination is of great importance in machines which must produce precision components with exceptionally good surface forms and textures.

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### Automation

In addition to research concerned with the performance of machine tools and their various elements, it is necessary to consider the functions of the machine tool on a much wider basis. First, the integration of the machine tool into a production line must be considered, and secondly the machining function must be integrated with other functions such as product design, planning, and inspection. The principal problems associated with integration arise mainly in the fields of work handling, regulation, and control, &c., and are now commonly studied under the general heading of "Automation."

The development of many types of machine tool has reached the stage where all the movements required to machine the work can be included in an automatic cycle. However, the linking together of machines so that work can pass progressively from machine to machine without human intervention involves a new set of problems related principally to work handling, and the overall regulation and control of the automatic line. Work handling includes all the functions involved in loading and unloading the automatic line correctly, orientating the work, bringing the work into correct time relation with the machine, locating and clamping the work in the machine, transferring the work from machine to machine, &c. Methods of orientation and transfer are sought which avoid excessive mechanical complication and exploit such properties as the shape, balance, weight, &c., of the part to be handled. There is a great need for systematic investigations of the fundamental properties of common forms of components occurring in various branches of engineering.

If individual machines in an automatic line are to be left without operators, systems must be developed for the control of work quality, the detection of faulty operation, the initiation of machine shut-down, and the regulation of individual machine outputs according to the state of work flow along the line. In this field, increasing use is being made of pneumatic, electrical, and electronic control equipment to measure work size, detect the state of loading, &c., of critical parts of a machine line, evaluate this information and signal the necessary corrective actions. The essential concept employed in this type of control is that of feedback.

### Ergonomics and Machine Tools

Ergonomics has been roughly defined as the business of doing more work with less effort. It is usually the study of man in relation to his working environment, and involves the application of anatomical, physiological, and sociological knowledge to reduce human fatigue and increase working efficiency. To-day the application of ergonomics may extend far beyond what is normally considered as work, but in industry alone the results of ergonomic studies have been applied to the design of machine controls, seating, lighting, and other factors affecting workers, and have resulted in considerable improvements in efficiency.

Although progressive mechanisation has lowered the physical content of manual work in general, this has frequently been achieved at the expense of greater sensory or intellectual effort, thus creating new work-situations in which the combined mental and physical strains give rise to much greater fatigue than heavy physical work. Despite the growth of automation the functional unit in much of industry to-day is still the man and the machine. They must be considered together when searching for higher efficiency, and hence many different facets of man and his working environment are now being studied, including perceptual problems in observing counters and dials, the range and strength of joint movements, layout of controls, problems of seating and posture, body size and work spaces, the physiological effects of climate, factors affecting the speed and accuracy of control movements, problems of load-carrying, noise, vibration, &c. The progress which has already been made in this field has been a triumph of teamwork in which anatomists, experimental psychologists, physiologists, physicians, engineers, and other specialists have all played important parts. The application of ergonomics to machine tools, either as individual machines or in groups still gives great scope for improving the man-machine relation.

### Conclusion

Metal-cutting is an extremely wasteful process. Expensive plant is used to produce components which on average weigh about 60 per cent of the bought-in material, the remaining 40 per cent being cut into chips which, in the case of steel, for example, are worth less than 10 per cent of the initial material value.

Nevertheless, despite this inefficiency of metal cutting and the rapid growth of more efficient metal-forming processes such as extrusion and precision forging, the machine tool population of Britain is still over a million machines. This involves an immense capital investment in machinery and a very high expenditure in man-hours to operate and maintain the machines. Thus the significance of machine tools in Britain's economic development and ability to compete as an industrial nation is such that every effort should be made to achieve the highest standards in design, construction, and utilisation. This can be done only by the closest co-operation between makers and users, aided where necessary by scientific research establishments equipped to solve the fundamental and practical problems which prescribe the present limits of metal-cutting practice.

The information and recommendations given in the paper are presented as a contribution to the discussion of some of these problems. The fact that they are based on extensive research and development programmes in which many reputable makers and users are participating, justifies the serious consideration by machine tool manufacturers and users as a whole. To-day the power of science is such that what is regarded as futuristic in one decade is often commonplace in the next. It may be that some of the challenging new frontiers which have recently been opened in machine tool and metal-cutting development will, within the next ten or twenty years, make the tools and techniques of to-day seem as outmoded as those of the nineteenth century seem now.

# Glass Level Control

We illustrate some components of a system for automatic control of the level of molten glass in the furnace forehearth which has been installed at the St. Helens (Lancs.) works of Forster's Glass Company, Ltd. The system uses radioactive cobalt isotopes for level detection and operates through potentiometer controllers supplied by Honeywell Controls, Ltd., Greenford, Middlesex. Fig. 1 shows the emitter from which the cobalt-60 radiation is directed through the trough carrying molten glass from the furnace (the wall of which is seen on the left). A detector is mounted at the other side of the trough and produces a signal until the glass reaches the level at which the beam or radiation is interrupted. The signal is fed to an amplifier, the output of which operates a Honeywell continuous-balance potentiometer controller. The emitter, detector and amplifier were supplied by Isotope Developments, Ltd., 120, Moorgate Street, London, E.C.2. Fig. 2 shows the amplifier and the controller, the output from which while radiation is detected or interrupted controls a variable-speed gearbox on the batch chargers. Control of the level is obtained to within 0·01in. The radiation source has a useful life of four to five years, and mounting of the emitter and detector is external to the trough, requiring no apertures or structural modification.

The equipment described above is part of an automatic control system at the works covering four regenerative furnaces designed by Forster's Glass Company, Ltd., two unit melters by Ernhart (U.K.), Ltd.; also ten batch chargers and twenty feeders. Temperature control to ±0·1 per cent is applied to the channels and spouts of all feeders by means of "Radiamatic" radiation pyrometers.

Control instruments for each furnace are panel mounted and include Honeywell two-point strip chart recorders for recording reference temperatures in both working end and melting end of the furnace in conjunction with "Radiamatic" and thermocouple detectors.

Fig. 1—Emitter of cobalt isotope system for measuring glass level in furnace forehearth

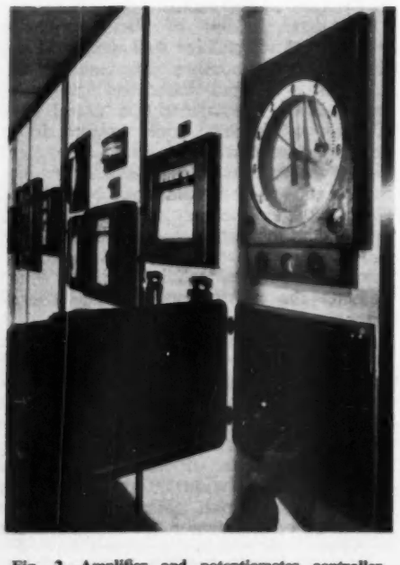

Fig. 2—Amplifier and potentiometer controller of glass level control system

THE ENGINEER

Technical Contributors Section

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# Investigation of Cut-off and Throttle Governing of Petrol Engines*

By DR. MAHMOUD HASSAAN SAADAWI, Ph.D., M.Sc., B.Sc., M.S.A.E.,†

*To regulate the output of a mixture-compressing engine without changing its speed is liable to cause large and possibly adverse changes in its efficiency at light loads. If the homogeneous charge is retained, the worst effects of control by a throttle at reduced loads can be avoided by varying the charge quantity by changing the point of inlet valve closure. However, increasing efficiency can only be approached (in the homogeneous charge case) at reduced loads by varying the compression ratio.*

## 1—THEORETICAL ANALYSIS

### 1.1. Introduction

It is generally known that most researches dealing with the performance of internal combustion engines are mainly carried out at full load conditions which are met with in practice only for short periods. However, motor-car petrol engines work most of the time at less than half load and therefore improving the efficiency at light loads is of great importance. To obtain this improvement, previous investigators used the hit-and-miss governing, the stratification of the charge, the increased ignition advance or as lean a mixture as possible to get best efficiency at three-quarters to quarter load. These methods were either inapplicable or did not show enough satisfactory improvement.

L. G. Esmond Morse,[1] H. Hiedl[2] and D. R. Pye[3] showed that with throttled engines the power absorbed in pumping the charge in and out of the cylinder is the chief cause of the great falling off in the efficiency of such engines at light loads. A certain amount of fuel should be consumed at no load due to the fact that some positive work must be done in the cylinder to balance the negative work created by pumping the charge at no load. However, if the pumping losses are not taken into consideration, the indicated thermal efficiencies at partial and at full load are almost the same. When pumping losses are taken into account, the efficiency at partial loads will be less, due to the fact that the net output is reduced by the increase of pumping losses. Comparing two indicator diagrams of a petrol engine, one at full load and the other at partial load, it will be found that the ratio of the pumping losses to the positive work is much more at partial load than at full load. For example, the ratio of pumping losses to positive work as calculated by the author from indicator diagrams taken by Ricardo[4] with an optical indicator under rapid and complete combustion on his engine at full throttle is 1 : 8·9 and this ratio becomes 1 : 4·77 in case of reduced throttle. The author measured the pumping mean effective pressure in the two diagrams as 3·81 lb per square inch at full load and 5·2 lb per square inch at partial load. This is explained by the fact that as the load decreases, the positive area of the diagram decreases while the pumping losses increase.

Pumping losses are due to pressure drop in the cylinder caused by the restriction to the flow of the mixture at : (i) the throttle ; (ii) the induction pipe ; and (iii) the valves. At partial loads the increase in pressure drop is mainly due to throttling, since the effect of the pressure drop caused by (ii) and (iii) is less than at full load owing to the smaller charge passing.

It is thus clear that one of the main factors in improving the efficiency of petrol engines at partial loads is decreasing the pumping losses. This is attempted in this present research by keeping the throttle full open and varying the admission period during the suction stroke by means of cams of variable angles of duration. Keeping the throttle full open will reduce the depression created in the cylinder and consequently will reduce the negative loop. In Ricardo's[4] opinion, the area of the suction loop and therefore the fluid losses could be reduced by reducing the period of opening of the inlet valve instead of by throttling, but the author is not aware of any practical work carried out to this effect. The problem of the pumping loss during suction stroke requires a thorough investigation, which should be of great value to designers since it would enable them not only to reduce the pumping losses but also to increase the volumetric efficiency.

Further, it is well known that the efficiency of petrol engines increases with the increase of compression ratio ; the limit in this case is the pressure at the end of compression stroke, or in other words "detonation." At partial loads and for the same compression ratio, the compression pressure will be reduced because of throttling. It would thus be possible to increase the compression

* This work is a part of a research ("The Effect on Petrol Engine Performance of Cut-off and Throttle Governing," Faculty of Engineering, Giza, Egypt, April, 1948) carried out by the author for the M.Sc. (Eng.) degree in the Heat Engine Laboratory at the Faculty of Engineering, Giza, in 1948.

† Lecturer in Mechanical Engineering, Faculty of Engineering, Cairo University, Giza, Egypt.

*Symbols, Terms and Definitions*

The effective volume is the volume of the charge during compression stroke when the pressure inside the cylinder is equal to the outside pressure.

The effective compression ratio is the ratio between the effective volume and clearance volume.

The effective volumetric efficiency is the ratio between the volume swept by the piston at the moment when the pressure of the charge inside the cylinder is equal to the outside pressure at the temperature and pressure of the surrounding air, and the total piston displacement volume.

$V_c$—Clearance volume.

$V_1$—Volume of the charge at the moment of valve closure with cut-off $+ V_c$.

$V_s$—Swept volume $+ V_c$.

$V_e$—Volume of charge when pressure of the charge in the cylinder is the same as the outside pressure during compression stroke ($V_e$ called effective volume) $+ V_c$.

$P_1$—The suction pressure in kilogrammes per square centimetre.

$P_2$—Pressure at the end of suction stroke in kilogrammes per square centimetre.

$P_0$—Outside atmospheric pressure (= 1·03 kg per square centimetre).

$P_c$—Compression pressure in kilogrammes per square centimetre.

$P_z$—Maximum pressure in kilogrammes per square centimetre.

$n$—Index of the volume in $PV^n = C$.

ratio at partial loads, so that the compression pressure is the same at all loads, without detonation taking place; this increase of compression ratio at partial loads would result in an increase in thermal efficiency. The change of compression ratio with load could be attained practically by decreasing the compression space with decrease of load.

In the experimental engine described later, this is done by means of a movable piston in the cylinder-head. This method is called the variation of the clearance volume.

### 1.2. Theoretical Analysis of the Throttling and Cut-Off Methods

In the following, a theoretical analysis is given of the pumping losses under throttling and cut-off methods to illustrate the value of the methods suggested by the author before: namely, cut-off governing and variation of the clearance volume. Since pumping losses are proportional to the area of the suction loop, the variation of this area will be considered in the following theoretical analysis.

According to the indicator diagram, Fig. 1,

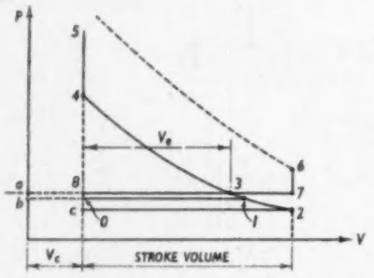



**Fig. 1—Suction loop with: (1) throttle governing =area : c238; (2) cut-off governing=area : 0138**

the area of the suction loop with cut-off governing will be 0138

$$=(\text{area under } 13+\text{area under } 3a)-(\text{area under } bl+\text{area } ab08).$$

$$\text{But area under } 13=\frac{P_3V_3-P_1V_1}{n-1},$$

$$\text{area under } 3a=P_3V_3,$$

$$\text{area under } bl=P_1V_1,$$

$$\text{and area } ab08=(P_2-P_1)V_C.$$

Therefore the suction loop area

$$=\left(\frac{P_3V_3-P_1V_1}{n-1}+P_3V_3\right)-[P_1V_1+(P_2-P_1)\times V_C]$$

$$=\frac{P_3V_3-P_1V_1}{n-1}+(P_3V_3-P_1V_1)-(P_2-P_1)\times V_C$$

$$=\frac{n}{n-1}(P_3V_3-P_1V_1)-V_C(P_2-P_1) \quad . \; . \; (1)$$

The suction pressure with each cut-off is that corresponding to the suction pressure at full throttle and is assumed to be 0·98 kg per square centimetre. The area of the suction loop was calculated for air as the working substance and for different cut-off percentages varying from 100 per cent to 50 per cent of the suction stroke.

Similarly, the suction loop area with the throttle governing is given by the area c 238 (Fig. 1):

$$=\frac{n}{n-1}(P_3V_3-P_2V_2)-V_C(P_2-P_2) \quad . \; . \; (2)$$

The area of the suction loop for throttling was calculated for suction pressures varying from 0·98 kg to 0·6 kg per square centimetre. These correspond to full load and partial loads respectively.

In these calculations, the wall and residual gases effects have been neglected. To calculate the theoretical diagrams the actual engine clearance and swept volume, its standard compression ratio and the compression pressure at full throttle and with this compression ratio and the minimum clearance volume with variable compression ratio head, were used. In dealing, later on, with the decrease of pumping losses and their effect on engine efficiency and performance, the compression ratio, adjusted to 4·05 for the experimental engine at full throttle with normal timing, will be taken as a basis of compression. This standard condition corresponds to a clearance volume of 700 c.c., a compression pressure 6·48 kg per square centimetre and a suction loop area 111·56 kg per centimetre. While the first data were obtained by measurement from the actual engine, the latter figures were obtained by calculation. The following results of calculations were obtained with the different cases which have been investigated.

### 1.3. Results of Calculations

*Case A: Throttle governing, with constant valve closure at 15 deg. after bottom dead centre and constant compression pressure (variable clearance volume).*—The above procedure of calculation was followed to determine the different state points of the diagram (Fig. 1) and to estimate the suction loop area for different values of suction pressure from 0·98 kg per square centimetre down to 0·60 kg per square centimetre. The minimum value (0·6 kg per square centimetre) is fixed by the minimum clearance volume obtainable with the variable head (as will be shown later). It is known from the previous analysis of different methods of governing that with throttling at partial loads, the effective compression ratio is decreased and thus the compression pressure will be lower. To keep the compression pressure at all partial loads at its value for full throttle, the clearance volume at reduced loads must be decreased. The minimum clearance volume with the variable head is 444 c.c. and this corresponds to suction pressure about 0·6 kg per square centimetre. The results of calculation are plotted in Fig. 2.

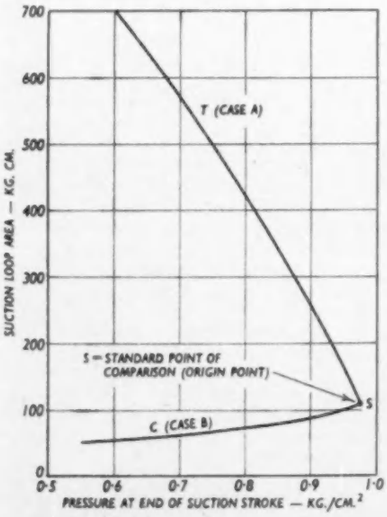



**Fig. 2—Relation between pressure at end of suction stroke and suction loop area with throttle governing, Case *A* (constant compression pressure) and cut-off governing, Case *B* (constant compression pressure)**

*Case B: Cut-off governing, with variable valve closure and constant compression pressure (variable clearance volume).*—The solution of the pumping losses problem is carried out by assuming that we can govern the valve closure by varying the point at which the inlet valve closes and keeping the instant of opening of this valve the same. In order to obtain partial loads the inlet valve closure is advanced, during the suction stroke, towards the inner dead centre. Calculations were made with each case of cut-off to determine the corresponding compression ratio, suction loop area and pressure at the end of suction stroke. The results of calculations are shown in Fig. 2 where *T* (throttling) represents Case *A* and *C* (cut-off) represents Case *B*. The difference in pumping losses in the two cases of throttling and cut-off governing at constant compression pressure and at the same pressure at the end of the suction stroke can be obtained from curves *T* and *C*.

Fig. 2 shows that the area of the suction loop (neglecting the effect of friction in the induction pipe restriction at the valve, temperature and diagram factor) is 111·56 kg per centimetre at full throttle and maximum duration of valve opening. This value is increased to 700 kg per centimetre with throttling for a suction pressure =0·6 kg per square centimetre and is decreased to 55·9 kg per centimetre with the cam which closes the inlet valve at 60 per cent of the suction stroke. Fig. 3 shows the variation of compression ratio with the percentage of suction stroke at inlet valve closure.

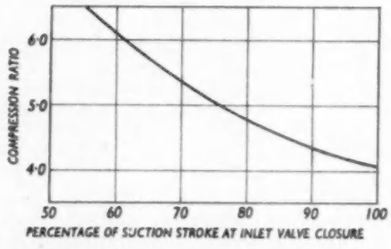



**Fig. 3—Variation of compression ratio with percentage of suction stroke at inlet valve closure, for Case *B* (cut-off governing and constant compression pressure)**

*Suction Loop Areas with Case C: Throttle governing, with constant valve closure at 15 deg. after bottom dead centre and constant clearance volume 700 c.c. (variable compression pressure) and with Case D=Cut-off governing, with variable valve closure and constant clearance volume 700 c.c. (variable compression pressure).*—If the clearance volume is kept constant with any given throttle opening or any given valve opening period the pressure at the end of compression will decrease as the load is reduced. Fig. 4 shows the pressure at end of suction stroke, as abscissa against the calculated suction loop area as ordinate. Fig. 5 gives the variation of compression pressure against the percentage of suction stroke at inlet valve closure (Case *D*).

With throttling, the value of the compression pressure at full throttle is 6·48 kg per square centimetre and this value drops to 3·97 kg per square centimetre when suction pressure is 0·6 kg per square centimetre and keeping the clearance volume the same. The suction loop area increases in this case from 111·56 kg per centimetre to 693 kg per

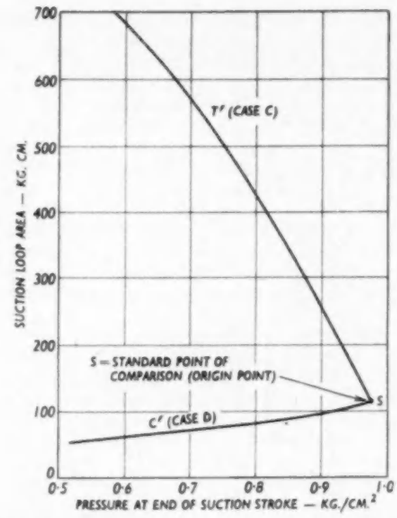

SUCTION LOOP AREA — KG. CM.
PRESSURE AT END OF SUCTION STROKE — KG./CM.²
T' (CASE C)
C' (CASE D)
S = STANDARD POINT OF COMPARISON (ORIGIN POINT)
S

**Fig. 4—Relation between pressure at end of suction stroke and suction loop area with throttle governing, Case *C* (constant clearance volume) and cut-off governing, Case *D* (constant clearance volume)**

centimetre. The suction loop area with cut-off and constant clearance varies between 111·56 kg per centimetre with normal timing and 53·3 kg per centimetre with inlet valve closure at 50 per cent of the suction stroke. The compression pressure drops from 6·48 kg per square centimetre at 100 per cent stroke closure to 3·30 kg per square centimetre at 50 per cent stroke valve closure.

1.4. *Conclusions and Discussion of Results.*—(1) Adopting cut-off governing instead of throttle governing will result in a reduction of pumping losses with decreasing load. This is shown clearly in Fig. 2. The pumping losses at full load are the same for both cut-off and throttle governing, this is shown by point *S* (Fig. 2). Curve *C* shows the variation of pumping losses with decreasing load and cut-off governing while *T* shows the variation with throttle governing. It is seen from this figure that when the load is decreased, for example, to a value corresponding to 60 per cent of stroke at valve closure, the pumping losses will decrease to about 50 per cent of its value at full throttle, while with throttle governing pumping losses will increase to about six times the value at full throttle. This is a marked improvement in favour of the cut-off governing method.

(2) The results given in Fig. 2 are for the case when the compression pressure is kept constant in all cases by varying the clearance volume. It will be remembered that this fulfils also the second suggestion made by the author earlier. If, however, the clearance volume is kept constant, the results are still

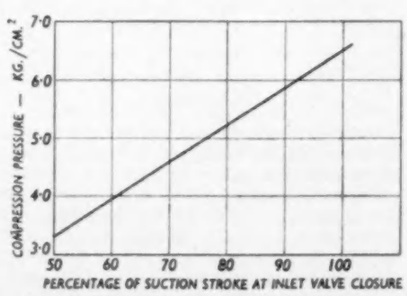



**Fig. 5—Variation of compression pressure with percentage of suction stroke at inlet valve closure for Case *D* (cut-off governing and constant clearance volume)**

in favour of the cut-off method. This is shown by Fig. 4. It is seen from this figure that curves *C'* and *T'*, giving respectively the variation of pumping losses for throttle and cut-off governing, show the same characteristics as curves *C* and *T* in Fig. 2, but with a slight difference in the variation of pumping losses with load.

(3) The variation of the pressure at the end of the compression stroke with different cut-off is given in Fig. 5. It is seen from this figure that if the cut-off is changed from 100 to 60 per cent of the suction stroke, the compression pressure will drop from 6·48 kg per square centimetre to 3·99 kg per square centimetre. As stated before, the clearance volume could be changed to keep the compression pressure continuously at the higher value of 6·48 kg per square centimetre. The compression ratio, in order to obtain this, will increase from 4·05 to 6·1 (Fig. 3), and naturally this will be followed by an increase in thermal efficiency. Estimating the effect of this change in compression ratio on the air standard basis, the efficiency will increase from 42·8 to 51·5 per cent—an increase of 8·7 per cent or about 20 per cent of the lower limit of the air standard.

## 2—ENGINE, APPARATUS AND METHOD OF MEASUREMENT

### 2.1. Engine

A 6–9 b.h.p., 500 to 600 r.p.m., single-cylinder vertical four-stroke, " L "-type Lister engine was used. The cylinder is 5·5in bore by 5·5in stroke, and has a clearance volume of 700 c.c. with the standard head. The

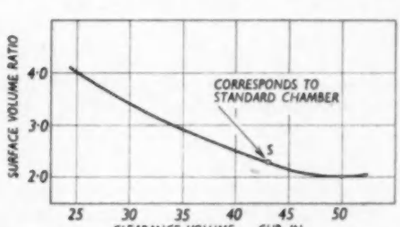



**Fig. 6—Relation between surface volume ratio and compression ratio**

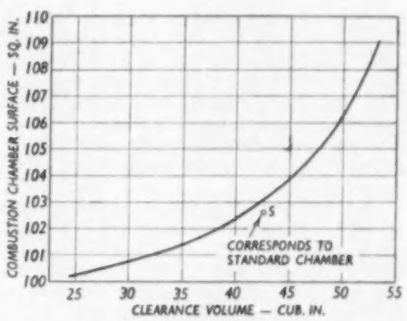



**Fig. 7—Relation between surface volume ratio and clearance volume**

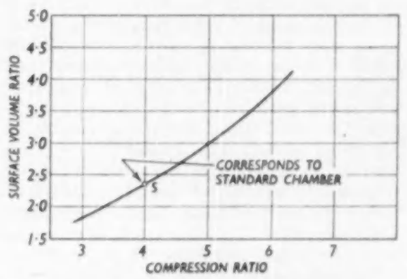



**Fig. 8—Variation of combustion chamber surface and clearance volume**

engine was provided with a variable clearance cylinder-head‡ which had been manufactured in the Faculty of Engineering workshop. Minimum clearance volume with this head is 444 c.c.

Analysis of the combustion chamber surface and characteristics are shown in Fig. 9. Development of combustion chamber surface is taken from the minimum clearance volume up to the flush position of the upper piston. A comparison of this chamber with the standard one is indicated by point *S* on the curves (Figs. 6, 7 and 8), which were obtained from the analysis of Fig. 10. It is clear that the surface volume ratio ranges from 1·95 at a compression ratio 3·25 to 4·00 at a compression ratio

‡ Designed by Professor C. A. Geneve.

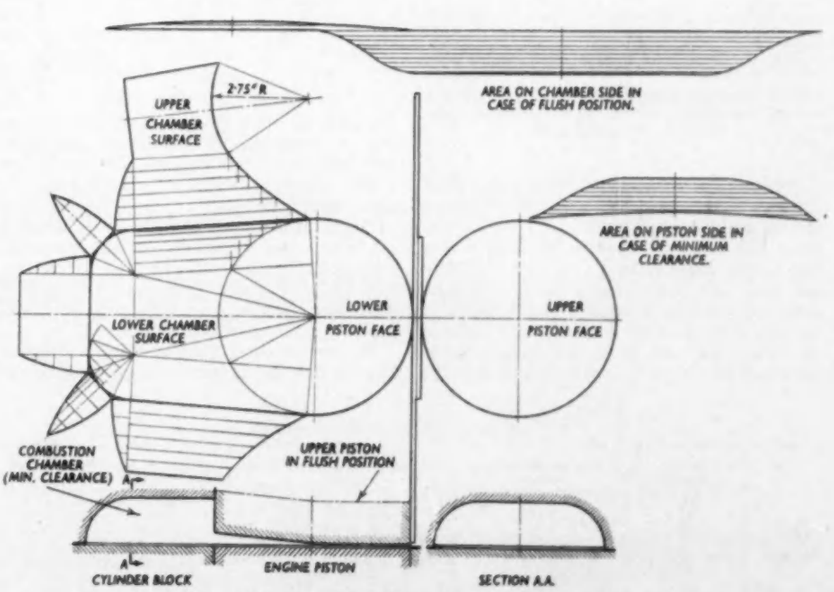


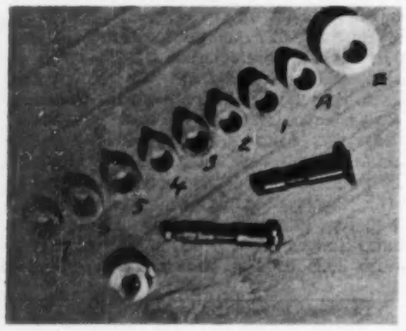

**Fig. 9—Combustion chamber surface and characteristics**

6·2, and with the standard chamber, surface volume ratio=2·39 at a compression ratio 4·05. Though the variation in surface volume ratio is rather great yet it acts in a direction which reduces the efficiency as the compression ratio is increased; therefore any improvement in efficiency will be definitely due to the increase in compression ratio only.

The ratio of the connecting-rod to crank is 4·36. With the normal engine, the inlet valve opens 15 deg. before top dead centre and closes 15 deg. after bottom dead centre. With standard tappet clearance of 0·004in, the inlet valve maximum lift= 0·295in. From the drawings of the image of the connecting-rod and crank at different positions we found that we could not keep the normal shape of the cam and inlet valve lift at its standard value because the maximum early closure of valve which could be attained is at 15 deg. before bottom dead centre and therefore our range of early closure lies between 15 deg. before and 15 deg. after bottom dead centre, which is of no use at all and corresponds to 1·455 per cent of the stroke. Also the maximum lift is going to be reduced rapidly. Therefore, alteration of both cam profile and tappet was essential.

### 2.2. Apparatus

A series of seven cams shown in the photograph (Fig. 10) designed to open the valve at the same crank angle and to close it at different positions of the stroke, covering a range from 100 per cent suction stroke to 45 per cent of it measured from inner dead centre. Every cam has a certain opening period and the same valve lift except the three last cams which have a reduced one due to the small duration of valve opening and the two flanks being nearer to each other. Comparison between the normal and the new cams on Fig. 11 shows that the rate of valve rise and drop per unit time is increased as the nose is getting smaller. In the case of cams closing at 60 and 45 per cent of the stroke, conditions are not ideal and valve drive is noisy, for this reason the engine speed was reduced to 430 and 470 r.p.m. during the tests.



(1) 100 per cent stroke closure cam, (2) 93 per cent stroke closure cam, (3) 90 per cent stroke closure cam, (4) 80 per cent stroke closure cam, (5) 70 per cent stroke closure cam, (6) 60 per cent stroke closure cam, (7) 45 per cent stroke closure cam, (A) normal cam, (E) eccentric used for making the profile of each cam.

**Fig. 10—Showing the series of the new cams used with cut off, normal cam, normal flat foot follower, roller follower, new tappet guide**

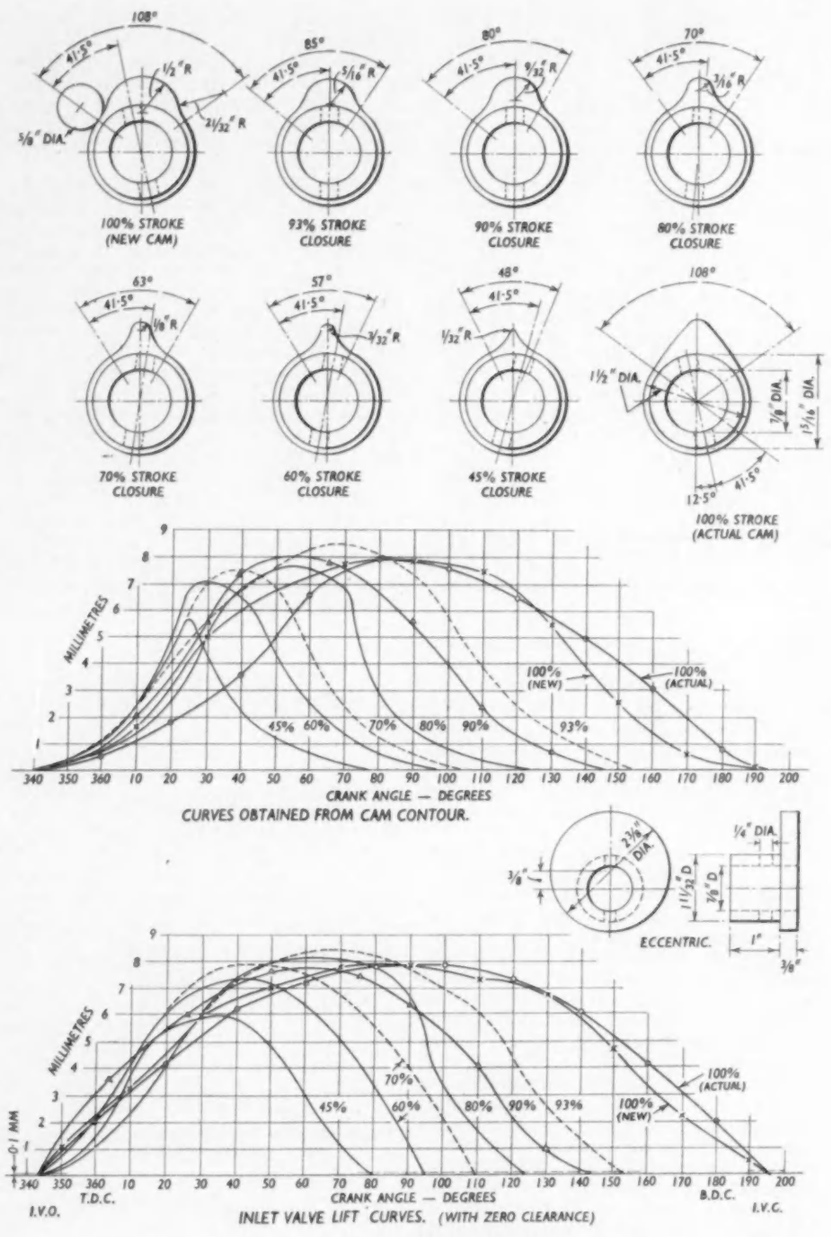



**Fig. 11—Profile and lift of series of cams**

Great care was taken in manufacturing the new cams according to the drawings and duration suggested as shown in Fig. 11. The following table gives design figures of the cams. Timing was estimated on drawing and checked after erection.

The new tappet is made as nearly as possible like the flat foot tappet. A slot is opened at the end to take a roller $\frac{3}{8}$in diameter. Eccentricity between the axis of the follower and mid-plane of flank in case of flat foot is omitted in the case of the roller by shifting the cam on the camshaft.

The tappet was guided in such a way as to have the axis of roller parallel to the camshaft.

*Table of Design Figures of the New Cams*

| Cam No. | Stroke, percentage | Piston displacement in inches | Inlet valve opens, degrees crank angle | Inlet valve closes, degrees crank angle |
|---|---|---|---|---|
| 1 | 100 | 5·38 | 15 deg. before T.D.C. | 15 deg. after outer D.C. |
| 2 | 93 | 5·11 | 15 deg. before T.D.C. | 27·5 deg. before outer D.C. |
| 3 | 90 | 4·95 | 15 deg. before T.D.C. | 40 deg. before outer D.C. |
| 4 | 80 | 4·38 | 15 deg. before T.D.C. | 58 deg. before outer D.C. |
| 5 | 70 | 3·83 | 15 deg. before T.D.C. | 73 deg. before outer D.C. |
| 6 | 60 | 3·32 | 15 deg. before T.D.C. | 85 deg. before outer D.C. |
| 7 | 45 | 2·52 | 15 deg. before T.D.C. | 102 deg. before outer D.C. |
| Actual | 100 | 5·38 | 15 deg. before T.D.C. | 15 deg. after outer D.C. |

### 2.3. Methods of Measurements and Equipment

Indicated horsepower is measured by taking cards by means of a Maihak high-speed indicator driven through a system of pulleys and strings. The motion is taken from a slider crank mechanism driven directly from the crankshaft through a universal joint. The indicator is connected to the combustion chamber by a very short passage to reduce throttling, cooling in the passage, &c. All springs were carefully calibrated. The engine loading is made by a direct current electric dynamometer, having a

floating yoke. The dynamometer is used for both loading and motoring the engine. Speed is observed on a speedometer, chain-driven from the engine shaft, and was checked by a revolution counter.

Alteration in the standard fuel system of the Lister engine was made to facilitate the process of metering the fuel. The fuel tank, being very low, does not allow the fuel consumption to be measured easily ; it was therefore raised to a head about 1·25m above the carburetter chamber and petrol, instead of being supplied by the fuel pump, was allowed to flow by gravity and the fuel pump was put out of action. To prevent flooding, the author designed a new float chamber which was added to the carburetter to provide regulation of the petrol head.

**The float operates a needle valve on its conical seat on the supply side. The float rotated about an axis which is screwed with the chamber.** The latter rests inside a holding sleeve which can be screwed or unscrewed inside the bracket. Therefore the holding sleeve can be rotated easily between the float chamber and the bracket. This rotation allows the chamber to be lowered or raised until the level of the petrol in the chamber allows no flooding at the carburetter. The supply and delivery branches are flexible to allow the chamber vertical movement.

The fuel, after leaving the main tank supported against the wall, can fill two metering vessels of known capacities, 124 c.c. and 164 c.c. respectively. The vessels are made of two truncated cones to allow a gradual change in flow area when the engine supply pipe is connected to measuring vessels.

Mixture strength range can be adjusted by the carburetter needle valve on the main jet or raising the level in the float chamber, therefore increasing the head at the jet.

Measurement of air consumption was a problem which required many trials, as there is no definite rule for choosing the damping volume in the case of pulsating flow in internal combustion engines. After trials made with different air boxes, the damping volume used was 460 litres. This volume corresponds to 215 times the stroke volume.

The volume recommended by W. Watson and H. Schofield[5] was 490 litres.

This damping volume proved satisfactory to damp any pulsations and gave a depression after the orifice up to 2in of water indicated on an inclined manometer. Orifices $\frac{1}{8}$in, $\frac{1}{4}$in, $\frac{3}{8}$in, 1in and $1\frac{1}{4}$in were turned successively on the lathe and reamered in zinc plates of thickness 0·4mm.[6]

The amount of flow required depends upon the throttle opening and the brake horse-power ; therefore the orifice must be selected according to the figure of the flow written opposite it in the standard tables.[5] The orifice must be chosen so as not to produce throttling at the engine and at the same time to give a reasonable head on the manometer.

Correction of the air flow was according to charts and correction factors of Diedrichs and Andrae.[7]

From the theoretical analysis shown earlier, we determine that with each cam the throttle must be fixed at its full open position. Also, in order to determine the corresponding throttle opening, in the case of throttle governing, the throttle adjustment must be sensitive so as to give the opening accurately. Therefore, a mechanism was designed to actuate the lever of the throttle and to give fine adjustment by hand.

The engine was motored with each cam and conditions of speed, compression pressure, temperature and induction pressure were

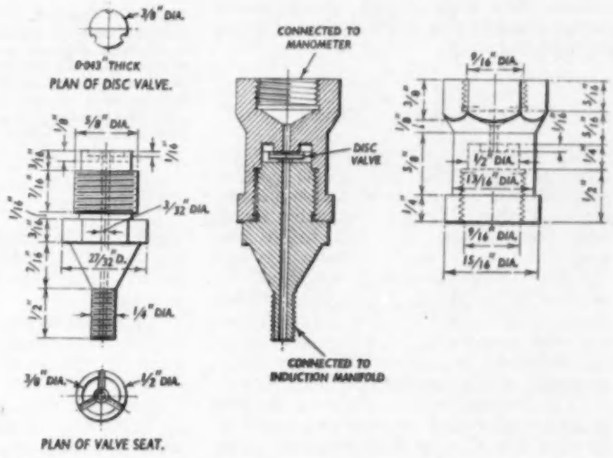



Fig. 12—Induction pressure valve

observed. The engine was then motored again with the normal timing and the previous conditions were obtained with the same compression pressure. The appropriate throttle opening was marked on a scale and this was repeated with each throttle opening.

A system of constant 6V battery and induction coil was used for ignition. The sparking plug was placed in all tests above the exhaust valve. The timing of the spark was indicated on a graduated disc and a pointer. Alternation in timing was made by a hand-operated screw which changed the phase angle between the spark distribution shaft and the cage holding the circuit breaker.

Mercury thermometers were used to measure inlet and outlet temperature of cooling water of the engine. A separate thermometer was used to measure the outlet temperature of cooling water coming out from the upper piston in the variable clearance cylinder-head in order to have all the cooling medium round the chamber at the same temperature. The amount of cooling water was measured by a calibrated orifice.

A calibrated Okill maximum pressure indicator was fitted to the engine for the purpose of indicating compression pressure in the case of motoring and the maximum pressure in the case of normal running. It was connected to the combustion chamber through a cooled cock to protect the indicator from continuous heating.

A special type of indicator was evolved and designed to measure the induction pressure.[8] The arrangement shown in Fig. 12 consists essentially of a non-return valve in the form of a light steel disc $\frac{1}{8}$in in diameter and 0·043in thick, moving between two annular seatings machined in the body of the instrument. The distance between the two seatings was adjusted so as to allow the disc a travel of 0·02in. It may be argued that the thickness of the valve disc and in turn the weight of the valve would have an effect on the measurement of the induction pressure. However, since the results will be mainly qualitative and of comparative value the valve disc thickness would not affect the result. In the drawing the seating on the left is screwed on the induction pipe after the butterfly valve and as near as possible to the inlet valve, and is furnished with radial grooves. The upper seat is plane, and is connected to a mercury tube exposed to atmosphere on one side, and allows the maximum depression in pipe to be indicated, i.e. when inlet valve is opened.

## 3—EXPERIMENTS AND RESULTS

The aim of these practical tests is to determine the actual improvement in performance when using cut-off governing. The experimental work carried out to support the methods suggested earlier for the improvements of petrol engine efficiencies at partial loads is presented here under two main headings: (1) Motoring tests; (2) Loading tests.

While motoring tests were carried out at the beginning because of their simplicity, and to obtain as much information as possible,

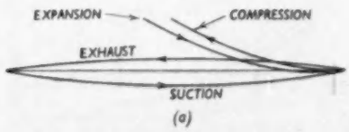



Fig. 13 (*a*)—Motoring indicator diagram with full open throttle and closure of the inlet valve at 100 per cent of the suction stroke (constant clearance volume = 700 c.c.)

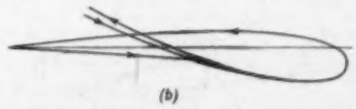



Fig. 13 (*b*)—Motoring indicator diagram with full throttle opening and closure of the inlet valve at 70 per cent of the suction stroke (constant clearance volume = 700 c.c.)

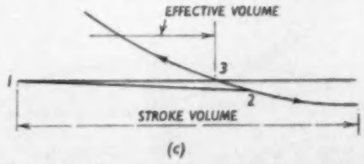



Fig. 13 (*c*)—Represents the suction loop area 123 with cut-off at 80 per cent closure (clearance volume = 700 c.c.)

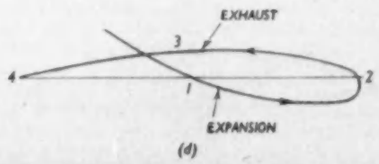



Fig. 13 (*d*)—Represents the exhaust loop area 1234 during motoring with 80 per cent stroke closure (clearance volume = 700 c.c.)

*N.B.*—In the above diagrams : Clearance volume = 700 c.c.; Speed = 630 r.p.m.; Spring scale 1 kg = 8mm.

loading tests were carried out to prove further points which could not be obtained by motoring tests.

### 3.1. Motoring Tests

*Test Procedure.*—The engine tappet and roller were placed in their proper position and each cam was in turn pinned on the camshaft. Tappet clearance and valve timing were checked with each cam before running. For every case the following were recorded : torque, speed, maximum depression in the manifold, compression pressure and air supply. In motoring the following were considered : (1) Pumping losses; (2) Induction pressure; (3) Compression pressure; (4) Volumetric efficiency.

3.1.1. *Pumping Losses Estimation.*—Analysis of different motoring indicator diagrams (Figs. 13 (*a*), 13 (*b*), 13 (*c*) and 13 (*d*) taken during these motoring experiments showed that taking the whole area of the motoring indicator diagram (suction loop plus exhaust loop) will not give a true picture of what happens during loading. The pumping losses when motoring actually consist of the suction loop, which is the same as when loading, and the exhaust loop, which is different with loading. The only way to compare the pumping losses in the two cases of the throttling and cut-off during loading is to consider the suction loop area only. This area decreases with earlier cut-off while the exhaust loop area is increased.

The diagrams used for separation of the suction loop with cut-off governing were taken for valve closure at 100, 93, 90, 80, 70 and 45 per cent of the suction stroke (Fig. 14 (*a*) to Fig. 14 (*f*)). For comparison the separation was also made for the motoring suction loop for the partial throttle openings corresponding to valve closure at 90, 80, 70 and 45 per cent stroke closure which give the same compression pressure as their corresponding cases of cut-off governing mentioned above (Fig. 15 (*a*) to Fig. 15 (*d*)). With both methods of governing the engine speed was 430 r.p.m. and the clearance volume was 700 c.c. The results are plotted in Fig. 16, which gives the change of suction pumping losses with percentage of stroke at valve closure. From this figure it is seen that the pumping losses during suction decrease with decrease of load with cut-off governing. The value of the pumping losses at 60 per cent closure is 50 per cent of the value of the losses at full throttle and standard timing. This ratio was obtained before by the theoretical results given in Fig. 4, where the areas of the suction loop are 61·4 kg per centimetre and 111·56 kg per centimetre at 60 and 100 per cent closure respectively. Therefore the results obtained by motoring follow the same characteristics and values as with theoretical investigations. With the throttle opening corresponding to 60 per cent stroke valve closure the losses are 1·6 times the losses at full throttle with normal timing ; in other words, the pumping losses increase with the decrease of load in the case of throttling.

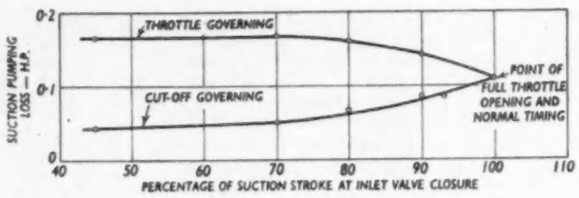



**Fig. 16 — Comparison of suction pumping loss horsepower with different percentages of cut-off and with their corresponding throttle opening so as to give the same compression pressure (clearance volume = 700 c.c; speed = 430 r.p.m.)**

It is thus concluded that the pumping losses with cut-off governing decrease as the load is decreased (with early valve closure) : for example, the pumping losses of 60 per cent closure are 50 per cent of the pumping losses at full throttle and normal valve closure, whereas the pumping losses at the throttle opening corresponding to 60 per cent valve closure exceed the pumping losses with full throttle opening and normal valve closure by 66 per cent (Fig. 16). This confirms the previous results obtained theoretically. The actual increase or decrease of the pumping losses are, however, different from the theoretical values obtained. This is mainly due to the variation of the actual diagram from the theoretical diagram.

3.1.2. *Effect of Cut-off Governing on the Induction Manifold Pressure.*—The maximum depression in the induction manifold was measured at points *C* and *T* (Fig. 17) corresponding to the point of closure of the inlet valve with cut-off and throttle governing respectively. The depression is recorded on a mercury U-tube by use of the induction pressure valve shown in Fig. 12. With cut-off, the depression decreases as the closure is getting earlier, due to the reduced flow of the charge through the valve, while the area of flow is kept the same through the inlet valve.

Fig. 18 represents the decrease of the depression in the induction manifold as the valve closure is changed from 100 per cent stroke closure to 60 per cent stroke closure. The depression varies from 80mm of mercury to 40mm. In case of throttling the depression changes from the value at full throttle and closure at the end of the suction stroke

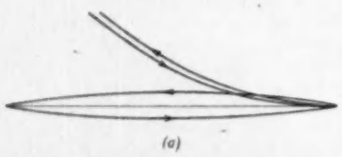



**Fig. 14 (*a*)—Suction and exhaust motoring pumping loops with 100 per cent stroke valve closure**

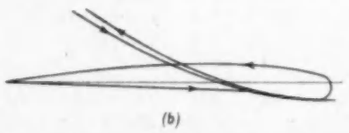



**Fig. 14 (*b*)—Suction and exhaust motoring pumping loops with 93 per cent stroke valve closure**

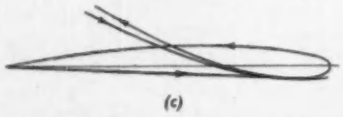



**Fig. 14 (*c*)—Suction and exhaust motoring pumping loops with 90 per cent stroke valve closure**

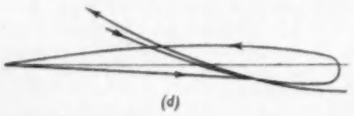



**Fig. 14 (*d*)—Suction and exhaust motoring pumping loops with 80 per cent stroke valve closure**

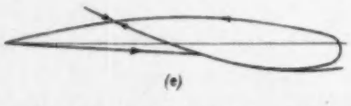



**Fig. 14 (*e*)—Suction and exhaust motoring pumping loops with 70 per cent stroke valve closure**

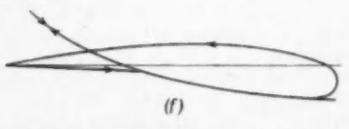



**Fig. 14 (*f*)—Suction and exhaust motoring pumping loops with 45 per cent stroke valve closure**

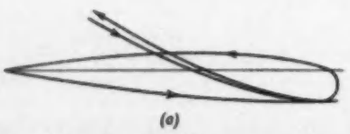



**Fig. 15 (*a*)—Suction and exhaust motoring pumping loops with the throttle opening of the same compression pressure as the 90 per cent stroke closure**

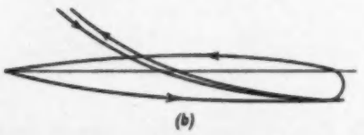



**Fig. 15 (*b*)—Suction and exhaust motoring pumping loops with the throttle opening of the same compression pressure as the 80 per cent stroke closure**

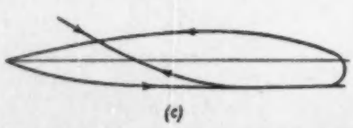



**Fig. 15 (*c*)—Suction and exhaust motoring pumping loops with the throttle opening of the same compression pressure as the 70 per cent stroke closure**

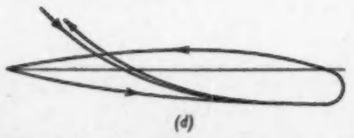



**Fig. 15 (*d*)—Suction and exhaust motoring pumping loops with the throttle opening of the same compression pressure as the 45 per cent stroke closure**

In Figs. 14 and 15 clearance volume = 700 c.c.; Speed = 430 r.p.m.; Spring scale 1 kg = 8mm.

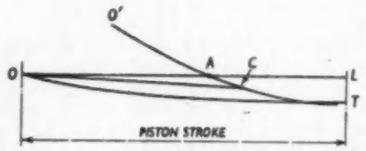



**Fig. 17—Diagram showing points *C* and *T* at which the depression in the manifold with cut-off *C* and throttle *T* is measured. *OL* = atmospheric line. *TCAO* = compression curve**

to 320mm at the throttle opening corresponding to 60 per cent stroke closure. The two curves have the same form as that obtained for pumping losses from the previous results obtained from the indicator diagram. The decrease in the depression of the induction manifold pressure with the early closure of the valve as shown by Fig. 18 is a good

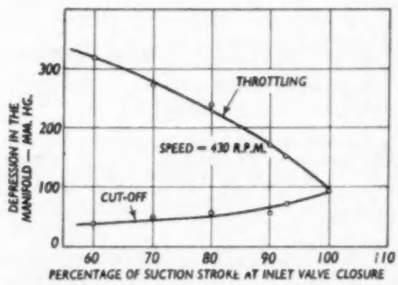



**Fig. 18—Comparison between the depression in the manifold with cut-off and throttling of the same compression pressure**

indication of the decrease in pumping losses with cut-off. Again, since with cut-off the variation of the depression in the manifold is very small it is believed that the carburation problem will be easier to handle.

3.1.3. *Effect of Cut-off Governing on the Compression Pressure.*—For loading tests shown later, actual measurement of the compression pressure from motoring indicator cards was made with each valve closure to obtain the clearance volume suitable to keep the compression pressure the same as its standard value (4·05 kg per square centimetre). Experiments have shown that to get the standard compression pressure with every cam the clearance volume of the combustion chamber would have to be reduced to a value less than can be obtained with the variable compression head for which the minimum clearance volume is 444 c.c. Accordingly, curves (Figs. 19

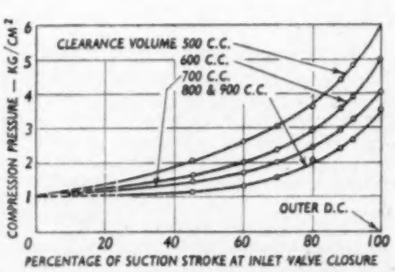



**Fig. 19—Variation of compression pressure with percentage of suction stroke at inlet valve closure for the same clearance volume**

and 20) were derived from experimental results. Fig. 19 gives the variation of compression pressure due to a variation in the time of closure of the inlet valve at constant clearance volume. Fig. 20 shows the variation of clearance volume with the percentage of valve closure for the same compression pressure 4·0 kg and 3·0 kg per square centimetre. With 3·0 kg per square centimetre we get a wider range of clearance volume and piston displacement.

The corresponding values of compression ratios that give the same compression pressure

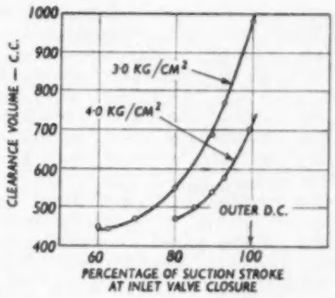



**Fig. 20—Variation of clearance volume with percentage of suction stroke at inlet valve closure for the same compression pressure**

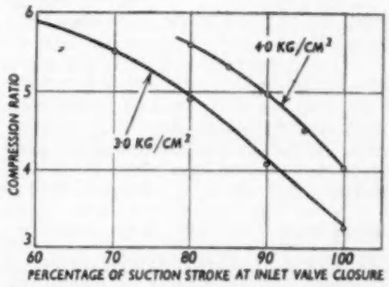



**Fig. 21—Change of compression ratio with percentage of suction stroke at inlet valve closure for the same compression pressure**

of 3·0 kg and 4·0 kg per square centimetre at each valve closure are shown in Fig. 21. It is seen from this figure that there is an increase of compression ratio with decrease of load and, therefore, this will improve thermal efficiency with partial loads.

3.1.4. *Volumetric Efficiency.*—From the measurement of volumetric efficiency with each valve closure at different speeds, the relation between the volumetric efficiency at the standard clearance volume and inlet valve closure in crank angles was obtained in Fig. 22 for speeds 460, 500 and 540 r.p.m. This figure shows that the relation is a straight line relation, the drop shown in Fig. 22 at the valve closure of 60 and 70 per cent is due to sudden closure of

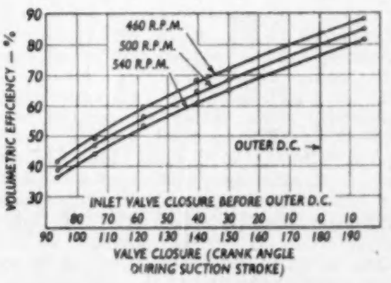



**Fig. 22—Relation between volumetric efficiency and inlet valve closure in crank angle at the same speed**

the valve with the cams which close the inlet valve at 60 and 70 per cent of the stroke. These cams have small angle of duration and reduced lift of 7·1mm and 7·8mm respectively, while the lift with the other cams is 8mm. The volumetric efficiency at the standard clearance volume for the cam which closes the inlet valve at 45 per cent and for its corresponding throttle opening

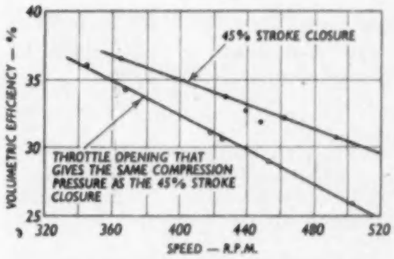



**Fig. 23—Change of volumetric efficiency with engine speed with 45 per cent cut-off and its corresponding throttle opening**

(which gives the same compression pressure) is given in Fig. 23.

The figure shows that throttling decreases the volumetric efficiency at a higher rate than cut-off. The difference between the two curves increases as the speed increases. This is mainly caused by restriction due to butterfly throttle. For example, the ratio between volumetric efficiency with throttling to volumetric efficiency with cut-off at speeds 400 and 500 r.p.m. (Fig. 23) is :

$$\frac{32 \cdot 25}{35} = 0 \cdot 92 \text{ and } \frac{26}{30 \cdot 5} = 0 \cdot 823.$$

The effective volumetric efficiency as measured from indicator diagrams corresponding to stroke valve closure from 100 to 45 per cent varies between 96 to 27 per cent at a speed of 430 r.p.m. Fig. 24 shows that the

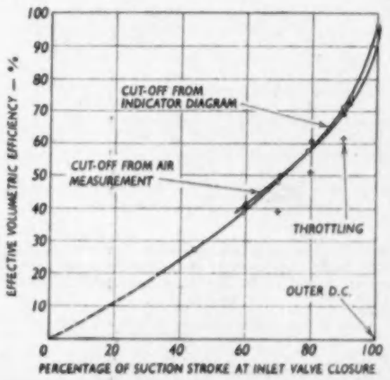



**Fig. 24—Variation of effective volumetric efficiency with percentage of suction stroke at inlet valve closure. Points marked by a cross belong to throttling of the same compression pressure. (This curve is deduced from motoring indicator diagrams with cut-off)**

curve drawn between the effective volumetric efficiency and percentage of the suction stroke at valve closure has the same shape and values approximately as that obtained from air measurement at a speed of 430 r.p.m. The curves show that volumetric efficiency drops rapidly up to about 75 per cent of the stroke. It shows little variation for the range from 50 to 75 per cent of the stroke, i.e. at the period when the connecting-rod is nearly at right-angles to the crank, and then it drops again until it reaches zero at the origin. Again, the points marked with a cross show that for the same conditions, the volumetric efficiency with throttling is less than the volumetric efficiency with cut-off.

### 3.2. Loading Tests

The performance of the engine was recorded under the following cases :

(*a*) Throttle governing with the standard clearance volume (constant compression ratio).

(*b*) Throttle governing with constant compression pressure (variable clearance volume).

(*c*) Cut-off governing with the standard clearance volume (constant compression ratio).

(*d*) Cut-off governing with constant compression pressure (variable clearance volume).

In loading tests the engine speed was kept constant at 470 r.p.m. and the air to fuel ratio by weight was maintained at 13·7 : 1. The outlet cooling water temperature was 42·5 deg. Cent. and the ignition advance was adjusted for optimum conditions.

In the loading tests corresponding to cases (*c*) and (*d*) the cams which close the inlet valve at 60, 70, 80, 90, 93 and 100 per cent of the suction stroke were used. After the required cam was fitted on the engine camshaft in its proper position with tappet clearance at its standard value of 0·004in, the inlet valve timing was then checked and recorded. When steady conditions were obtained, observations of the different measurements of indicated horsepower, brake horsepower, exhaust temperature, inlet induction temperature and depression in the induction manifold system were recorded.

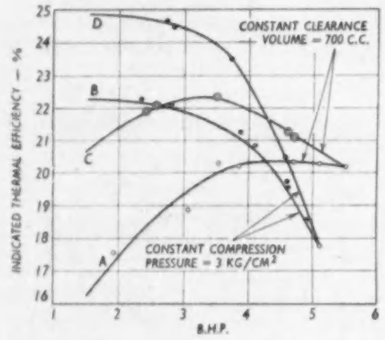



**Fig. 25—Variation of indicated thermal efficiency with brake horsepower for throttling and cut-off (curves *A* and *B* for throttling and curves *C* and *D* for cut-off)**

The results are plotted in Fig. 25 to Fig. 35. In these figures the curves representing the results obtained under any of the conditions mentioned above are denoted by the same alphabetical letter, i.e. curves *A* indicate results obtained under condition (*a*) and so on. These curves show the variation of the different factors against brake horsepower. The indicated thermal efficiency, brake thermal efficiency and mechanical efficiency were calculated and are included in the results.

3.2.1. *Effect of Cut-off Governing as Compared to Throttle Governing.*—Curves *A* and *C* in Fig. 25 giving the variation of the indicated thermal efficiency with brake horsepower (curve *A* being for the standard engine and curve *C* for cut-off governing) shows the improvement of the indicated thermal efficiency at light loads with the adoption of cut-off governing. This improvement is about 10·45 per cent at two-thirds of the load, 17·7 per cent at half load and 23·6 per cent at one-third of the load. It is also noticed that, while the efficiency with throttling remains almost constant down to nearly two-thirds load and then decreases with the decrease of load, in the case of cut-off governing the efficiency rises from its value at full load up to a maximum of 22·3 per cent (an increase of about 10·7 per cent of full load efficiency) at about two-thirds of the load and then decreases again as the load decreases. This is due mostly to the decrease of pumping losses at partial loads with cut-off governing. Lowering the temperature of the whole cycle with cut-off governing has also some effect in improving the efficiency. The decrease in thermal efficiency with cut-off governing at loads below half load may be due to increase of pumping losses due to the increase of the part of the pumping losses during exhaust stroke.

Curves *A* and *C* (Fig. 26) give the variation of the brake thermal efficiency with brake horsepower. These also show an improvement at all loads with cut-off governing ; the improvement is 13·25 per cent at two-thirds of the load and 16·6 per cent at half load. The brake thermal efficiency with throttling decreases from the full load value of 17·2 per cent to 11·6 per cent at one-third of the load. With cut-off governing it increases first from 17·2 to 18 per cent at two-thirds of the load and then decreases again with lower loads.

Therefore, adopting cut-off governing will give a gain in both the indicated and brake thermal efficiency, at partial loads, over throttle governing. This is very important since petrol engines work most of their life at about half load. What is more important is that the maximum thermal efficiency occurs, with cut-off, near half load, which, as just stated, is the load at which petrol engines work most of their life.

3.2.2. *Effect of Keeping the Compression Pressure Constant at All Loads with Both Kinds of Governing.*—In order to prove the second method, namely, keeping the compression pressure the same, the compression pressure was kept at a selected value of 3·0 kg per square centimetre. This value was chosen in order to cover the whole range of cut-off governing from 60 to 100 per cent stroke valve closure, since the minimum clearance volume obtainable in the engine is limited.

It is seen from curves *A* and *B* in Fig. 25 that keeping the compression pressure the same at all loads is very beneficial, since in this case the indicated thermal efficiency increases with the decrease of load, at a higher rate at first, but the rate of increase decreases with the further decrease of load (the increase at half loads is 24·2 per cent of the full load efficiency). These two curves show the effect of varying the clearance volume in order to obtain the same compression pressure at all loads. The difference of the indicated thermal efficiency at full load in both cases is due to the change of compression ratio (as stated before, a lower compression ratio was adopted at full throttle under condition (*b*), to cover the whole range of load).

Curve *D* of Fig. 25 shows the effect of both methods (namely, adopting of cut-off governing, combined with keeping the compression pressure the same at all loads) on the indicated thermal efficiency. It is seen that the increase of the indicated thermal efficiency is quite appreciable (being 38·8 per cent of the full load value at half load).

The variation of the brake thermal efficiency due to changing the compression ratio with load (keeping compression pressure the same) is shown by curve *B* in Fig. 26. It is seen from the curve that the rate of

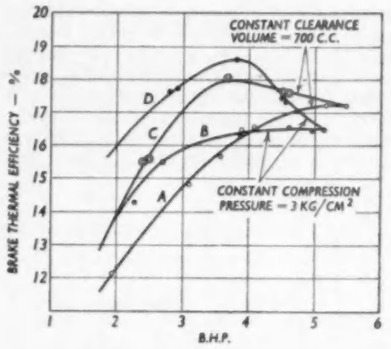



**Fig. 26—Variation of brake thermal efficiency with brake horsepower for throttling (curves *A* and *B*) and cut-off (curves *C* and *D*)**

decrease of the brake thermal efficiency with decrease of load is lower than that of the standard case (as given by curve *A*, Fig. 26). This means that keeping the compression pressure the same will improve the brake thermal efficiency at partial loads. The main reason is the improvement gained in indicated thermal efficiency, since the mechanical efficiency under condition (*b*) (constant compression pressure) is actually lower than the standard case (as shown by curves *A* and *B* in Fig. 27). This decrease in mechanical

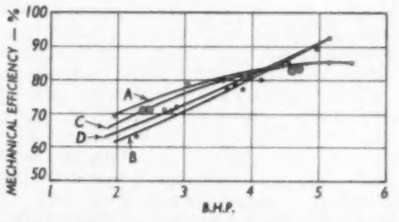



**Fig. 27—Change of mechanical efficiency with brake horsepower for throttling (curves *A* and *B*) and cut-off (curves *C* and *D*). *A* and *C*=constant clearance; *B* and *D*=constant compression pressure**

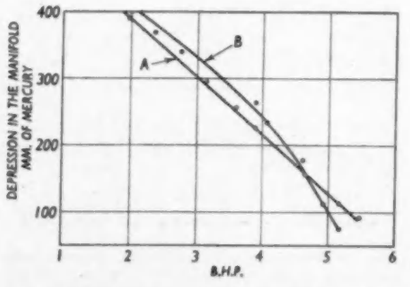



**Fig. 28—Showing change in depression in the manifold with brake horsepower in the two cases of throttling with constant clearance volume (curve *A*) and throttling and constant compression pressure (curve *B*)**

efficiency is due to : (*a*) bigger friction losses due to the fact that the cylinder pressure is higher, and (*b*) bigger pumping losses due to the fact that the throttle is less opened for the same load under condition (*b*); this is proved by comparing the depression in the manifold under conditions (*a*) and (*b*), as shown in Fig. 28).

The improvement in the brake thermal

efficiency under condition (*d*), where both methods (namely, adopting cut-off governing and keeping the compression pressure the same under all loads) are used, is shown by curve *D* (Fig. 26). It is seen from this figure that the maximum brake thermal efficiency is attained at about two-thirds the load. It should be remembered that the reason that curves *A* and *C* and curves *B* and *D* do not show the same value at full load is that a different compression ratio is used, as mentioned before.

3.2.3. *Effect on Mechanical Efficiency.*—Fig. 27, which gives the variation of the mechanical efficiency under the four conditions, shows clearly that adopting cut-off governing does not affect materially the mechanical efficiency (as seen from comparing curves *A* and *C*). Keeping the compression pressure constant results in a higher rate of decrease of mechanical efficiency at light loads.

3.2.4. *Effect on Compression Ratio of Keeping the Compression Pressure the Same at All Loads.*—In order to have the compression pressure the same at all loads, the clearance volume, and therefore the compression ratio, is altered as the load is changed by throttling or cut-off. As the load decreases the compression ratio is increased. The compression pressure is taken as 3·0 kg per square centimetre. Referring to curves *B* and *D* (Fig. 29),

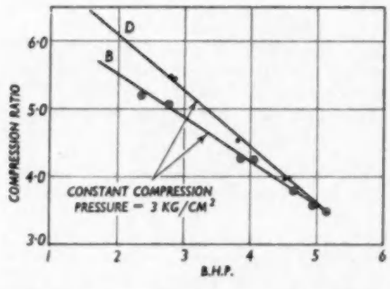



**Fig. 29—Change of compression ratio for different brake horsepower at constant compression pressure 3 kg per square centimetre; *B*=throttling; *D*=cut-off**

we get the relation between different loads and the compression ratio, which gives the same compression pressure for throttling and cut-off. It is seen from this figure that the compression ratio could be increased appreciably at light loads, and this is one of the main reasons for the improvement of the indicated thermal efficiency.

The ideal way of determining the allowable compression ratios at different loads is to determine the highest useful compression ratio at each load. This, however, was not possible with the existing engine and the method used, which is keeping the compression pressure the same, is the nearest method available.

It is again noticed that the increase of compression ratio with cut-off (curve *D*, Fig. 29) to give the same compression pressure is higher than with throttling (curve *B*, Fig. 29). This is due to the fact that for the same load, since the efficiency is higher with cut-off, a smaller input is needed, and this means less charge admitted into the cylinder with cut-off governing. Thus to bring this smaller charge to the same compression pressure, a higher compression ratio is used. A higher compression ratio with cut-off, at the same load, will result in a still better thermal efficiency.

3.2.5. *Effect on the Fuel Consumption.*—Adopting cut-off governing instead of throttling will give an economy in the specific fuel consumption per indicated or per brake horsepower. Referring to Fig. 30, curves *A*

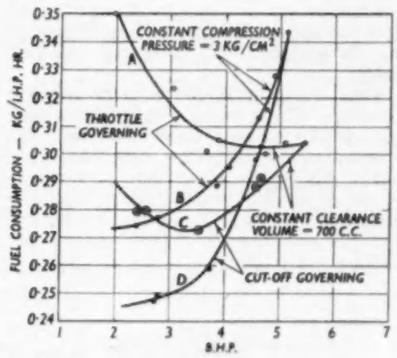



**Fig. 30—Variation of fuel consumption (per indicated horsepower hour in kilogrammes) with brake horsepower for both throttling and cut-off**

and *C* give the variation of the fuel consumption per indicated horsepower hour with load. It is clear that as the load is decreased by throttling the consumption is increased. At full load the consumption is 0·304 kg per indicated horsepower hour. This value increases to 0·308 at two-thirds load and to 0·324 kg per indicated horsepower hour at half load, whereas with cut-off the consumption decreases as the load is decreased by cut-off. At two-thirds load the consumption per indicated horsepower is 0·274 kg per hour, and at half load it amounts to 0·276 kg per hour. Between two-thirds and half load the consumption per indicated horsepower has a minimum value of 0·2725 kg per hour. The economy at half load=0·324—0·276=0·048 kg per hour. As regards the consumption per brake horsepower hour, curves *A* and *C* in Fig. 31 show its variation with change

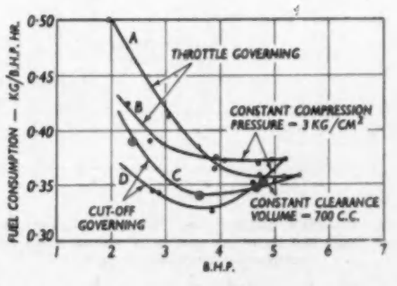



**Fig. 31—Variation of fuel consumption per brake horsepower hour with brake horsepower for throttling and cut-off**

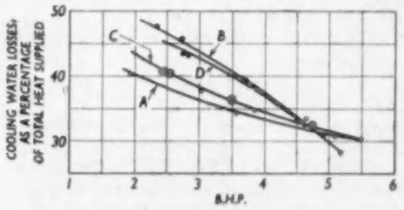
of load by throttling and cut-off respectively at constant clearance volume. Curve *A* (throttling) shows an increase in the consumption from 0·36 kg per brake horsepower hour at full load to 0·435 kg per brake horsepower hour at half load. Curve *C* (cut-off) gives a flat consumption curve from full load to two-thirds load and then the consumption increases as the load is decreased by cut-off. The consumption at two-thirds load=0·342 kg per brake horsepower hour, and at half load=0·370 kg per brake horsepower hour. The economy at half load=0·435—0·37=0·065 kg per brake horsepower hour.

If the compression pressure is kept constant at all loads we get a reduction in the fuel consumption as the load is decreased. Referring to curves *B* and *D* (Fig. 30) for throttling and cut-off respectively (at constant compression pressure), it is seen that there is a drop in the specific fuel consumption from 0·343 kg per indicated horsepower hour at full load to 0·284 kg per indicated horsepower hour at two-thirds load with throttling, and to 0·255 kg per indicated horsepower hour at two-thirds load with cut-off. The gain in fuel consumption between throttling and cut-off (constant compression pressure) at half load=0·276—0·247=0·029 kg per indicated horsepower hour.

When considering the consumption per brake horsepower with the two methods of governing at constant compression pressure, we get a flat consumption curve with throttling from full load to two-thirds load (curve *B*, Fig. 31) and then the consumption increases as the load is decreased by throttling. In case of cut-off the consumption curve (curve *D*, Fig. 31) goes down from 0·37 kg per brake horsepower hour at full load to 0·33 kg per brake horsepower hour at two-thirds load. The economy on fuel consumption at half load=0·405—0·35=0·055 kg per brake horsepower hour.

3.2.6. *Heat Balance Sheet.*—Though the purpose of these experiments was limited to the effect of cut-off on thermal efficiency only, it was decided to make the full heat balance sheet for half load, two-thirds load and full load under the same conditions as the experiments cited above when this unexpected result was found (see Figs. 34 and 35.)

(*a*) *Heat Lost to Cooling Water.*—Curves shown in Fig. 32 give the variation in the




Curves *A* and *B*=throttling; Curves *C* and *D*=cut-off; Curves *A* and *C*=constant clearance volume; Curves *B* and *D*=constant compression pressure

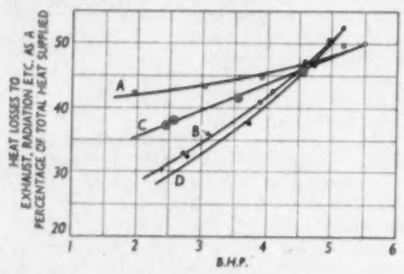
**Fig. 32—Relation between cooling water losses expressed as percentage of total heat supplied to engine and brake horsepower**

cooling water losses expressed as a percentage of total heat supplied. The cases of constant clearance volume are shown by curves *C* and *A* (cut-off and throttling respectively). The losses in this case of constant clearance volume are nearly the same in both cases with a slight increase in case of cut-off than with throttling. The cooling water losses increase as the load is reduced by cut-off or throttling, and the value of the losses in these cases is between 30 per cent at full load to 40 per cent at half load.

In cases of constant compression pressure the cooling water losses have a higher value due to the increase in the surface/volume ratio as the compression ratio is increased with reduced loads. Referring to curves *B* (throttling) and *D* (cut-off) it is observed that at reduced loads the losses with throttling are higher than with cut-off. At full

load the cooling water losses amount to 28 per cent of the total heat supplied. At half load the losses with cut-off are 44·5 per cent and with throttling are 46 per cent of the heat supplied.

(*b*) *Heat Lost to Exhaust, Radiation, &c.*— The heat lost to exhaust, radiation, &c. as calculated by subtracting the sum of the heat given to indicated power and heat to cooling water from the total heat supplied




Curves *A* and *B*=throttling ; Curves *C* and *D*=cut-off; Curves *A* and *C* =constant clearance; Curves *B* and *D*=constant compression pressure

**Fig. 33—Relation between exhaust, radiation, &c., losses, expressed as a percentage of total heat supplied to engine, and brake horsepower**

to the engine is shown plotted in Fig. 33. Curves *A* (throttling) and *C* (cut-off) are for the cases of constant clearance volume and curves *B* (throttling) and *D* (cut-off) are for the cases of constant compression pressure. Curve *C* shows less exhaust losses with cut-off than curve *A* with throttling. The gain increases as the load is decreased. The exhaust losses with throttling vary between 50 per cent at full load to 43 per cent at half load and with cut-off the losses vary between 50 per cent at full load to 38·5 per cent at half load.

The losses in the case of constant compression pressure have a lower value due to higher expansion ratio as the load is decreased. The difference between the losses with cut-off and throttling in this case is small. At two-thirds load the losses with cut-off are less than the losses with throttling by 2·0 per cent.

From curves in Figs. 25, 32 and 33 the heat balance sheets given in Figs. 34 and 35 are deduced for full, two-thirds and half loads.

Thus the gain in the case of constant clearance volume is mainly due to decreasing the suction pumping losses combined with a reduction in the heat lost to the exhaust.

The gain in case of constant compression pressure is due to decreasing pumping losses, an increase of compression ratio and a slight gain from both the exhaust and cooling water losses.

## 4.—CONCLUSIONS

The main aim of this work is to prove the value of the methods suggested, namely, adopting cut-off governing and increasing the compression ratio with increase of load

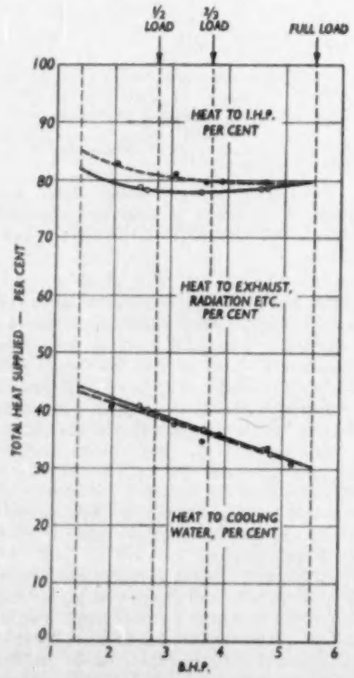



**Fig. 34—Heat balance sheet, for cut-off (shown in full lines) and throttling (shown in dotted lines) at constant clearance volume**

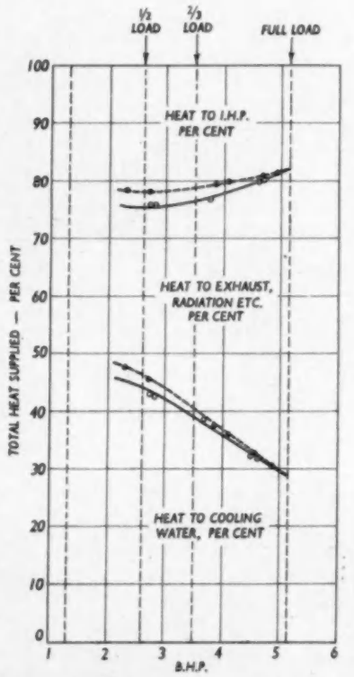



**Fig. 35—Heat balance sheet, for cut-off (shown in full lines) and throttling (shown in dotted lines) at constant compression pressure**

so as to keep the compression pressure constant at all loads, on the performance of petrol engines at partial loads. The question of the practical applications of this investigation is not at present considered.

In the motoring tests, which were used to estimate the suction pumping losses at different loads, it was proved that adopting cut-off governing will cause the pumping losses to decrease with a decrease in load. For example, it is estimated that at 60 per cent cut-off, the pumping loss will decrease to half its value at full load. If throttle governing was adopted, the pumping losses at a load corresponding to 60 per cent cut-off would be 1·6 times the pumping losses at full load.

It was shown also that the only correct way of estimating the pumping losses by motoring tests is to obtain an actual indicator diagram and separate the suction pumping losses from the pumping losses due to exhaust.

Loading tests (Section 3.2) showed that adopting cut-off governing will result in an appreciable gain in both indicated and brake thermal efficiencies at partial loads. Keeping the compression pressure the same will also result in an appreciable gain in thermal efficiency. When adopting both methods the gain is still bigger. For example, adopting cut-off governing will increase the indicated thermal efficiency by 10·45 per cent at two-thirds load, 17·7 per cent at half load. The corresponding gains in brake thermal efficiency are 13·25 and 16·6 per cent. The maximum brake thermal efficiency occurs at about half load. This percentage increase in thermal efficiency is very important since petrol engines are working most of their life between half and two-thirds load. Keeping the compression pressure the same will result, at half load, in an increase of 24·2 per cent in indicated thermal efficiency as compared with full load value.

If both methods are adopted the maximum indicated thermal efficiency occurs at about half load and is 138·8 per cent of the value at full load.

The appreciable gain in the performance of petrol engines at partial loads is due mainly to the improvement of indicated thermal efficiency as shown previously (Part 3.2). The effect of cut-off governing and keeping the compression pressure the same on mechanical efficiency is very small.

Thus this work proves that adopting cut-off governing and varying the clearance volume with load is very beneficial. The author, however, did not go into possible methods of applying these methods practically, but he feels that the very appreciable improvement gained will justify any mechanical complications which may be associated with the practical application.

### Acknowledgment

The author would like to thank Professors Dr. Abdel Rahman El-Sawy, C. A. Geneve and Dr. M. I. Fawzi for their continuous interest, invaluable help and advice while doing this research in the Heat Engine Laboratory of the Faculty of Engineering, Giza, Egypt.

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# Thermal Cycling Rigs for Nuclear Reactor Fuel Elements

## METHODS OF APPLYING MECHANICAL LOAD

By J. R. LINGE, D.C.Ae., A.F.R.Ae.S., A.M.I.Mech.E.*

*This article describes some of the problems associated with the design of equipment for thermal cycling tests on nuclear reactor fuel elements of the Calder Hall type with special reference to the development of devices for applying loads to the fuel element assemblies. For reference purposes the theoretical solution, indicating optimum dimensions for the design, is given in an appendix. Mention is made of a test rig which might be used to simulate the aerodynamic torque loads experienced by certain types of fuel element in a reactor channel. To provide a background, some of the difficulties associated with the design of equipment for thermal cycling rigs and the factors influencing the choice of method of thermal cycling are briefly discussed by way of introduction. It would appear that the novel method of applying end load described might well be applicable to other fields of test and investigation.*

THERMAL cycling, as the name implies, comprises the cycling of complete fuel elements between suitable temperature limits and other environmental conditions, such as external pressure, found in a gas-cooled nuclear reactor.

It has been accepted as a test procedure which can give a good indication of the service behaviour to be expected from certain design features incorporated in the fuel element, although it cannot provide an overall index of performance since there are a number of operational features, e.g. irradiation, which are impossible to reproduce.

The constructional features of the Calder Hall family of fuel elements, and variants, are too well known to warrant detailed description here. However, we might consider one important aspect of fuel element behaviour in service. The difference in thermal expansion of the uranium rod and the magnesium can material combined with the effect of external gas pressure gives rise to the phenomenon known as thermal ratchetting which is exceedingly troublesome if suitable steps are not taken to reduce the possibility of its initiation.

In the design stage a number of devices are applied to minimise thermal ratchetting and invariably these comprise various kinds of recesses. Usually the recesses take the form of knurled or machined grooves closely pitched at each end of the bar and adequately spaced along its length according to circumstances, into which the relatively soft magnesium can material is forced by hydrostatic pressure during manufacture.

The subjection of fuel elements to a high pressure during manufacture serves an additional purpose in so far as it helps to ensure that the external face of the uranium and internal face of the can material are forced into intimate contact, a prerequisite of good heat transfer characteristics.

While the fuel element is in the reactor the high pressure of the working gas assists in maintaining this contact and reduces the temperature drop across the interface. The solution to the problem of thermal ratchetting can be further advanced by suitable manipulation of the metallurgical properties of the uranium and magnesium alloy sheath.

In reactors having vertical channels it is essential that in service the fuel element is prevented from bowing under the influence of the end load resulting from the weight of the fuel elements above it, which it supports.

Some designs of fuel element incorporate streamlined members at their mid-length; should excessive bowing occur the members make contact with the wall of the channel and thereby prevent further lateral movement.

Yet another design makes use of individual graphite sleeves for each element through which the weight of the stack of elements is reacted and in this fashion the stresses in the elements are reduced to a minimum.

The most highly worked fuel element in a reactor channel is not necessarily that element which is exposed to the highest temperature or to the greatest load. Fig. 1, taken from reference 1, shows the temperature variation with distance along a channel in the centre zone of the graphite core, for the uranium, the fuel element can surface, and the bulk gas. The bottom fuel element which supports the column of elements above it is subjected to the highest load but to a low temperature.

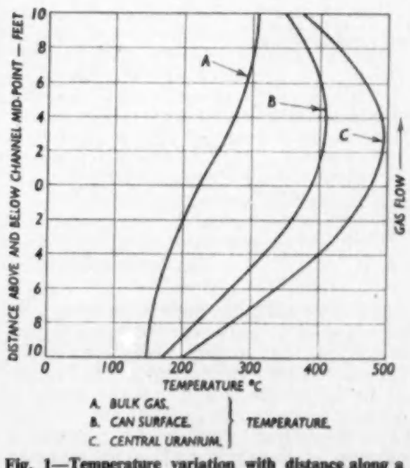



**Fig. 1—Temperature variation with distance along a channel in the centre zone of a reactor graphite core (reference 1)**

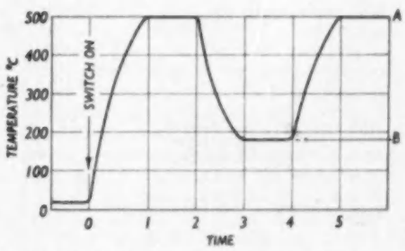
Therefore to cater for the extremes of load and temperature it is necessary to make the thermal cycling rig flexible in operation so that a range of temperatures and loads can be applied to the fuel element under test.

It is not necessary here to describe in detail the design of the fuel elements, it is sufficient to state that those employed at Calder Hall are representative of the type in mind. In general, nuclear considerations appear to lead to channels of between 4in to 4½in diameter associated with solid or tubular uranium fuel element bars somewhat greater than 1·0in in diameter. It is interesting to note that between 10kW and 20kW of heat have to be extracted from each foot length of fuel element.

### Rig Design Requirements

The following requirements formed the basis for the design of the thermal cycling and bow test rigs.

*Thermal Cycling Rig.*—(1) Thermal cycling between given temperature limits under a gas pressure of 200 lb per square inch at all times, irrespective of temperature. An illustrative temperature/time cycle is given in Fig. 2.




Period 1 to 2—Variable from one hour to three hours.
Period 2 to 3—Variable from quarter-hour to three hours.
Period 3 to 4—Variable from zero to two hours.
Period 0 to 1—Must be half-hour minimum.

**Fig. 2—Temperature/time cycle for thermal cycling rig**

(2) The imposition of a small cyclic variation in temperature of ±5 deg. to ±10 deg. Cent. on the upper dwell temperature to cater for local and transient changes occurring within the reactor.

(3) Facilities to impose a suitable and constant end load, within a given range of load, to the fuel element under test conditions representing the weight of the fuel elements above a given element in a fuel channel.

(4) Facilities for imposing a small torque loading to the fuel element to simulate the aerodynamic torque experienced by the element in the moderator channel.

(5) The mechanical design of the thermal cycling rig had to be arranged so as to accept fuel elements between 2ft and 4ft in length.

*Bow Test Rig.*—The proposed bow test basically consisted of submitting the fuel element to a given and constant end load, under pressure and at an elevated temperature.

Initially it was thought necessary to provide separate thermal cycling and bow test rigs but eventually a dual-purpose rig was evolved which could in theory cater for either eventuality by means of interchangeable units mounted on the top of the main pressure vessel containing the fuel element.

Thus, for example, six test rigs, nominally for thermal cycling, could with modification deal successfully with a current demand for either form of test, enabling the maximum use to be made of the equipment and floor space available.

### Types of Thermal Cycling Rigs

At the time the design studies were commenced little information, published or un-

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published, appeared to be available on the design of the test rigs under consideration; in consequence some time was spent in the early stages in deciding precisely what form the thermal cycling and bow test rigs should take.

There appeared to be a number of choices available and six conceivable approaches are now summarised.

(1) A pressure vessel large enough to house an electrical resistance furnace and fuel element, with external air, water, or moist air cooling.

(2) A pressure vessel of sufficient dimensions to contain the fuel element by itself with arrangements to enable the pressure vessel to be moved by mechanical means in and out of a large static furnace. Separate facilities were to be provided for cooling by air blast.

(3) A closed-loop pipe system employing pressurised gas circulated by a blower, the gas being heated or cooled at some convenient point in the system remote from the test section containing the fuel element.

(4) A design similar to (2) above but with heating effected by a low-frequency induction coil placed concentrically around the outside of the pressure vessel. Blast air provided the cooling medium.

(5) Two furnaces maintained at preset upper and lower cycling temperatures, both contained with a common pressure vessel with mechanical facilities for transferring the fuel element from one furnace to the other.

(6) A design similar to (4) above, but with the pressure vessel, and contained fuel element assembly, surrounded by a movable electric resistance furnace, again, with blast air as the cooling medium.

The first assembly described was soon found to be almost completely impracticable. This method, using air ducted round the outside of the pressure vessel was one of the first ideas investigated but calculations showed that the weight of a pressure vessel to contain a suitable furnace, and single fuel element would be high, about 250 lb, and in consequence the cooling time required, based on the maximum allowable thermal stress in the walls of the vessel (high grade steel) would be one hour and therefore greatly in excess of the one-half hour minimum period required.

The use of air saturated with water did not effectively alter the position. Methods of cooling using water pumped through coiled pipes within the pressure vessel and by passing cold $CO_2$ through the vessel in lieu of external air cooling were rejected for various reasons: in the first place, because of the drastic effects water might produce if brought suddenly into contact with hot steel at the temperatures involved and the probable necessity of having to preheat the water so as to bring the inlet temperature up to about 90 deg. Cent.

It was thought that in such latter circumstances the preheating would enable better control to be exercised over the rate of cooling by ensuring that the major proportion of heat being transferred would comprise a change of state, i.e. from water into steam. The probable high cost of the equipment coupled with the embarrassing possibility of having to discharge boiling water and steam, the alternative being to use a heat exchanger, did not make the scheme attractive.

Carbon dioxide cooling within the pressure vessel was rejected on the grounds of cost and the multiplicity of equipment required.

The second method, clearly unwieldy and cumbersome, was also inconvenient for many reasons.

The third method, believed at the time to be in use in this country, appeared complex and expensive so far as equipment was concerned.

Similar considerations applied to the fourth method but in addition methods (2), (3), and (4) proved inconvenient for various reasons, primarily the difficulty of applying end load to the fuel element within the pressure vessel.

The final choice therefore lay between methods (5) and (6).

Calculations indicated that cooling air supplied from large vertical stand pipes placed in a circle around the induction furnace, having holes drilled throughout their length through which air was blown tangentially on to the periphery of the pressure vessel, did not allow the pressure vessel and fuel element to be cooled to the required temperature within the given time period and furthermore necessitated an inconveniently large mass flow. It was thus clearly desirable to place some form of ducting round the induction furnace and pressure vessel in order to enable a reasonable mass flow of air to be utilised to the maximum effect. For this and for other reasons which are made clear later, method (6) was finally chosen.

The cooling time, (by radiation only) for a steel pressure vessel 6·0in external diameter, with $\frac{3}{16}$in thick walls and about 45in long, weighing approximately 50 lb and containing one fuel element was estimated to be about twenty-five minutes. Suitable external finning on the pressure vessel reduced the cooling time by radiation to nearly fifteen minutes. A further reduction of the cooling time to the order of five minutes could theoretically be achieved by ducting air around the outside of the pressure vessel (less radiation fins), at a flow rate of about 700 cubic feet per minute provided by a blower coupled to a 2 h.p. electric motor. A check on the magnitude of the thermal stresses which would arise in the walls of the pressure vessel showed that the maximum value to be expected would lie well within the capabilities of the material of construction.

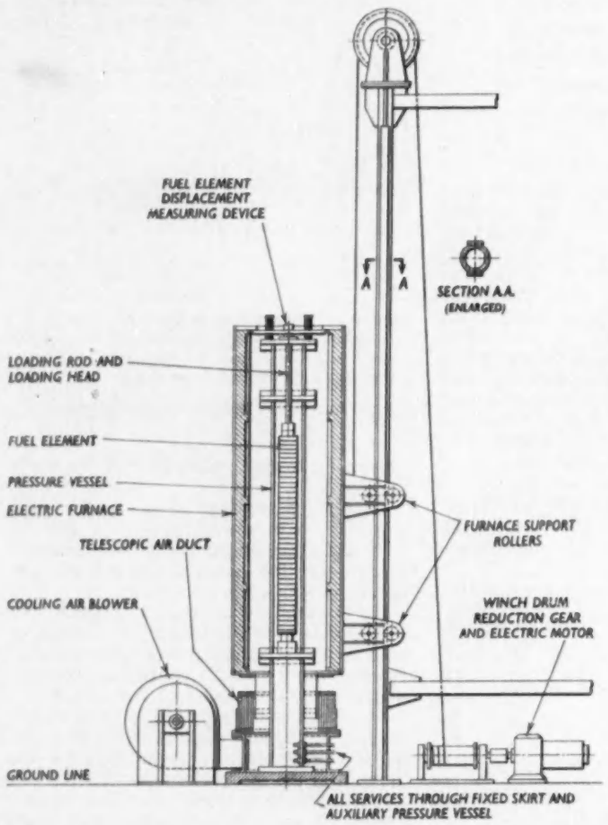


**Fig. 3—Schematic layout of finalised design for thermal cycling rig. Furnace shown in active position**

## Final Design

A schematic diagram of the finalised design is given in Fig. 3.

Basically the rig consists of a steel pressure vessel 6·0in external diameter long enough comfortably to house the longest fuel element projected, standing upon an extension or auxiliary pressure vessel. The latter enables the various services to be conveniently introduced into the main pressure vessel without fear of reducing clearances between the fuel element and the internal face of the main vessel, especially important in the case of the bow test rig. So far as pressure is concerned the main and auxiliary pressure vessels are freely connected. The main pressure vessel is surmounted by a smaller vessel containing the mechanical loading device and is sealed from it by a plate sandwiched between the assembly flanges.

The middle and upper vessels are surrounded by an electrical resistance furnace which is capable of being moved vertically on adjustable rollers clear of the two vessels during cycling operations. To the bottom of the furnace is attached a telescopic duct, which automatically extends (Fig. 4) as the furnace itself is lifted clear of the pressure vessels by an electric motor and double worm reduction gear.

Cooling air is then supplied by the blower

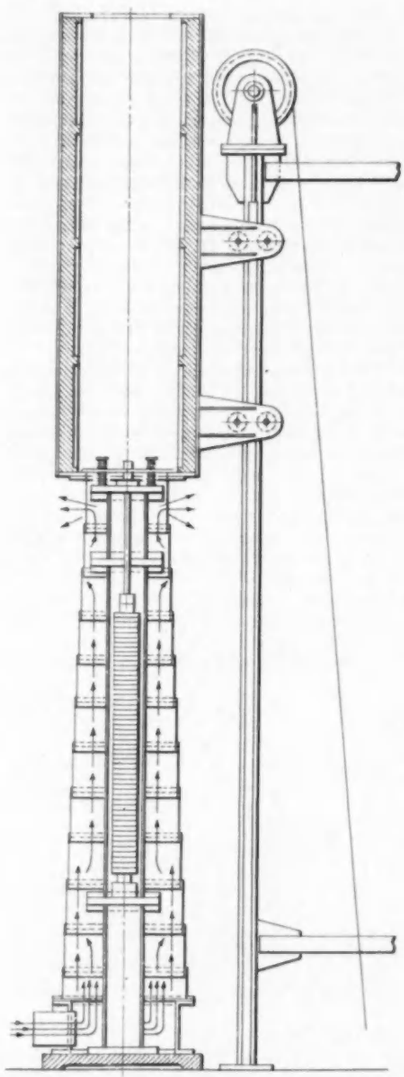

**Fig. 4—Schematic layout of finalised design for thermal cycling rig. Furnace shown in inactive position. The flow of cooling air from the centrifugal blower is clearly indicated by arrows**

situated to one side of a fixed skirt through which the various services were passed to the lower auxiliary pressure vessel. In outline the duct forms the frustrum of a long slender cone which not only facilitates mechanical construction but also facilitates cooling of the pressure vessel and its contents. The theoretical effect of placing the pressure vessel within a parallel duct and within a tapered duct is shown qualitatively in Fig. 5.

To avoid thermal cycling of the furnace heating elements exhaust air is allowed to escape via an annular space at the top of the upper pressure vessel. The advisability of switching the furnace off completely during the cooling cycle, i.e. with the furnace in the "up position" is considered to be problematical ; if the heating time is required to be short there appears to be a case for leaving the furnace running continuously (perhaps at half-power in the "up position"), in which event the cooling air if deflected at the base of the furnace minimises the amount of thermal cycling experienced by the furnace elements themselves ; venting of the cooling air in this manner, or a proportion of it, should therefore assist in prolonging the life of the furnace.

In one final design the air was prevented from entering the furnace by a spring mounted sealing plate attached to the closed end of the top pressure vessel ; sealing was then accomplished by the formation of intimate contact between this plate and an annular plate welded to the base of the furnace. The air was allowed to exhaust through holes pierced in the inner section of the ducting as indicated in Fig. 4.

*Furnace Design and Construction.*—To prevent excessive fall in temperature because of heat losses at the ends of the furnace, the overall length of the furnace must overlap the ends of the test specimen. The length is also partially influenced by the length of the individual heating sections which can be obtained ex-stock commercially, the delivery time for special designs being invariably excessive. Four sections are shown in the diagram, Fig. 4.

Apart from the ease of supply of standard heating elements it is in any case desirable to fabricate the furnace in this way since the control of the temperature distribution along the length of the furnace is made easier because the power input to the various electrical sections can be individually controlled. A gentle supply of air between the pressure vessel and furnace provided by the cooling blower running at low r.p.m. appears to be yet another method of minimising temperature gradients. The total power input of the furnace is 10kW to 15 kW and glass fibre insulation assists in keeping the total weight of the furnace and casing down to an estimated value of between 80 lb and 100 lb.

Strong points, not shown in the diagram, are provided so that the pressure vessel can be temporarily attached to the furnace and lifted with it under manual control when it is desired to examine or replace a fuel element. This requirement determines the overall height of the roller guides and the stiffness of the supporting structure.

## Thermal Cycling Operations

With reference to Fig. 2 the sequence of thermal cycling operations required to be controlled automatically is as follows :

(1) Load pressure vessel with fuel element and lower furnace into position.

(2) Switch on furnace until upper dwell temperature *A* is reached. Maintain furnace at temperature required for given period.

(3) Lift furnace clear of pressure vessel and reduce input to furnace to between half and zero power level.

(4) Switch on blower and cool pressure vessel to near stated lower dwell temperature *B*.

(5) Switch off blower, lower furnace, and maintain lower temperature *B*.

Individual events in the overall procedure described above are initiated by a process timer consisting of a synchronous motor driving six cams and associated microswitches via a gearbox. Change wheels in the gearbox enable the proposed range of dwell times listed below Fig. 2 to be achieved.

The electrical input to the furnace is controlled by energy regulators and the upper and lower dwell temperatures, *A* and *B* respectively, are held by means of two transistorised temperature controllers (0 deg. to 600 deg. Cent.), one for each temperature level. A third temperature controller connected to a thermocouple which is attached to one of the pressure vessel flange joints, or other critical location, is incorporated in the design as a safety cut-out to guard against any failure in the control of the upper temperature *A*. Separate means are provided for recording temperatures measured by thermocouples attached to the fuel element.

## Mechanisms for Applying End Load and Torque Load

*End Load.*—As has been previously mentioned it was required to make arrangements for the fuel element to be subjected to an external pressure of 200 lb per square inch at all times during thermal cycling. Carbon dioxide was selected for this purpose since it was available in suitable form for storage, it was also the gas chosen for the reactor itself. Since the furnace surrounded the pressure vessel and thus prevented access to the vessel when the former was elevated to the "up position" the only mode of entry to a gas-operated mechanical loading system was by way of the auxiliary pressure vessel or via the top of the furnace. The former method necessitated a length of piping from the auxiliary vessel up the main pressure vessel adjacent to the internal wall and hence into the mechanical loading device, a difficult obstruction to overcome in view of the small clearances available. Providing means could be applied to maintain the pressure of the $CO_2$ in the main and auxiliary vessels at a a constant value, irrespective of thermal cycling temperature changes, the supply for the loading device could be obtained directly from the main vessel without recourse to execessive runs of pipework and complicated joints.

The first and most obvious solution to the problem of applying constant end load to the fuel element which comes to mind is the utilisation of a dead weight. This is not unreasonable should small magnitudes of end load be required ; however, the application of a load of 160 lb, for example, demands a right cylinder in mild steel 5½in diameter and 2ft in length. This implies that the pressure vessel has to be extended in length to accommodate the weight and further, the thermal inertia of the system is, in consequence, increased by a not inconsiderable amount. Lead and lead alloys melt at temperatures well below 500 deg. Cent. ; G.E.C. heavy alloy, which has a specific gravity rather

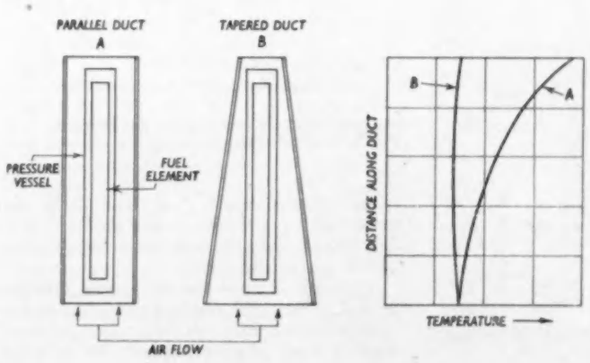


**Fig. 5—Qualitative temperature distribution for pressure vessel and fuel element in (*A*) parallel duct, and (*B*) tapered duct**

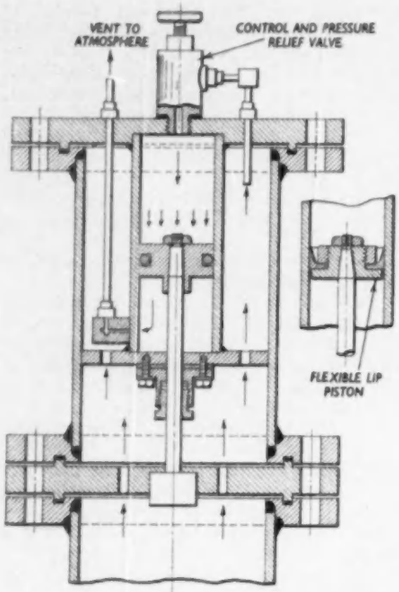


**Fig. 6—Schematic layout of proposed piston device for applying end load to a fuel element**

greater than that of lead, is suitable but is fairly expensive.

Another solution is the use of a gas-operated piston, (Fig. 6) with orthodox types of seals or, alternatively, the flexible lip piston which derives its sealing properties from a flexible walled annular ring firmly attached to the piston itself. Both these methods are extremely unattractive from the aspect of the unknown, but undoubtably large, amount of friction required to move the sliding elements of the system, coupled with "stiction" which is almost unavoidable. Various similar schemes were investigated theoretically and rejected on like grounds.

The most promising project, on paper, concerned the use of bellows both to effect the seal between the main and upper chambers and to provide the differential area upon which pressure could act in the upper chamber in order to realise a downward load on the fuel element. The general layout of the design is given in Fig. 7 with the arrangements for gas supply at pressure shown schematically. In principle the method of operation is straightforward.

The top and main pressure vessels are separated in the pressure sense by means of a plate sandwiched between the flanges of the joint. A long rod, the loading rod, is allowed to run in plain bearings carried in the sealing cap of the top vessel and in the common sealing plate. The resultant hole in this plate is sealed by means of a central bellow in stainless steel. The loading rod carries a suitable loading head, rigid or self aligning as required at the bottom end, and a device for measuring displacement at the upper end. Two other bellows, also in stainless steel, are attached to the sealing plate at their lower ends and are vented to atmosphere. The upper ends of all three bellows are attached to a cross-head which is in turn fastened to the loading rod.

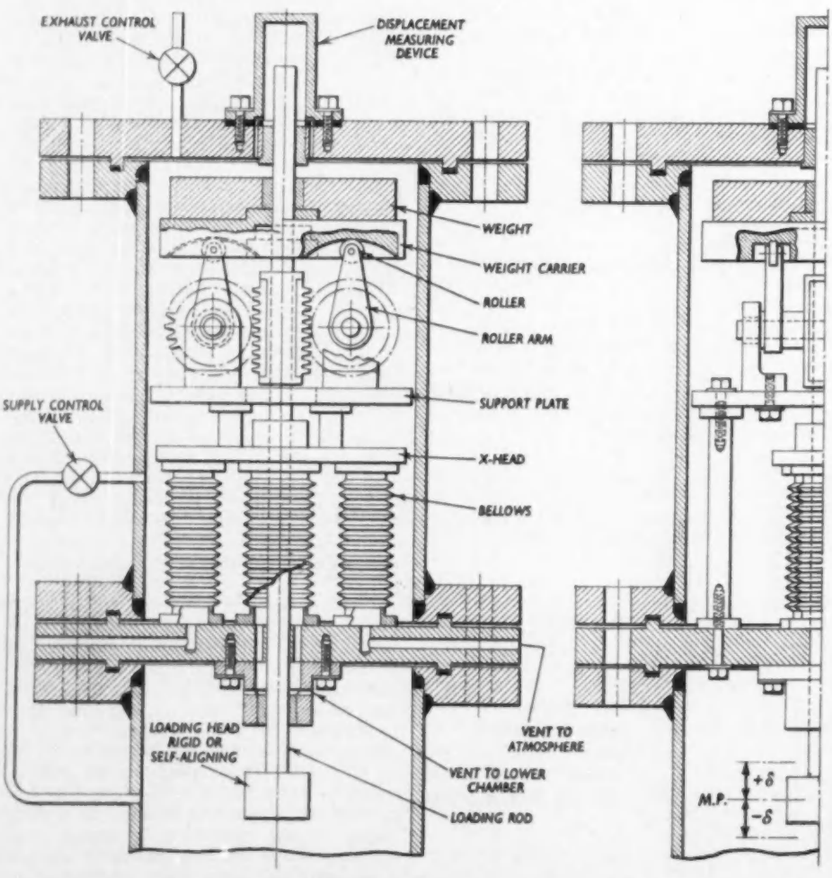


**Fig. 7—Schematic layout of proposed bellows design, with automatic compensation, for applying end load to a fuel element**

Carbon dioxide at constant pressure is led from the main chamber through a control valve to the upper chamber where it is vented to atmosphere through the exhaust control valve. By suitable adjustment of these valves the pressure in the top or loading chamber can be adjusted to any value between zero and 200 lb per square inch and hence end load is applied to the fuel element by virtue of the different pressures in both chambers combining to act on the differential areas of the bellows. However, as the loading rod is displaced up or down about its mean position, M.P., the combined spring stiffness of the bellows acting in parallel tends to make progressive changes in the load derived from the pressure in the top chamber.

To eliminate this effect a compensating device consisting of gears driven by a rack attached to the loading rod is introduced into the system as indicated in the diagram. Rollers, which are attached to the shaft common also to the gears and which rotate with them, support a weight carrier and compensating weight. By this means it is theoretically possible to eliminate almost completely the effect of the spring stiffness of the bellows.

Owing to a specified geometry of design, under conditions of a constant pressure of 200 lb per square inch in the main vessel, zero end load is obtained when the pressure

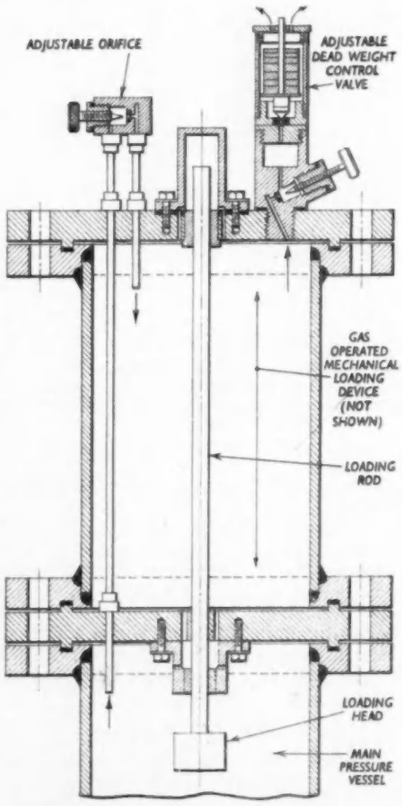


**Fig. 8—Gas supply arrangements for design shown in Fig. 7. The adjustable valves are not drawn to scale**

in the upper chamber is about 40 lb per square inch ; a maximum end load of 360 lb is achieved when the pressure is increased to 200 lb per square inch.

Appendix I gives the theoretical analysis of the system and demonstrates that within certain limits linearity of the applied pressure/applied load relationship can be achieved

to within less than 1 per cent. It is advisable to obtain the best possible accuracy in compensation since, owing to the change in the elastic properties of the stainless steel bellows between the upper and lower dwell temperatures, the spring stiffness of the bellows also changes by a gross amount of about 1½ per cent of the maximum obtainable end load, i.e. about 5 lb in 360 lb.

One possible layout for the gas supply arrangements is shown in Fig. 8. The main supply pipe is taken through a connection in the sealing plate adjacent to the wall of the upper chamber to an adjustable orifice which can be manually preset. A valve with adjustable dead-weight control limits the rate at which $CO_2$ exhausts into the atmosphere by means of a variable orifice working in conjunction with a vertical needle valve held down by small weights capable of being incrementally decreased or increased to suit the rate of leakage required. The gas leaking past the orifice is contained in the small chamber below the needle valve until it reaches the pressure required to lift the needle valve.

The relief of a large and uncontrollable volume of gas from the chamber is prevented by the adjustable orifice and thereby the valve allows $CO_2$ to puff into the atmosphere in small quantities. A consideration of the volumes of gas involved suggests that gas losses would be comparatively small. Devices to store excess gas blown off during the increasing temperature part of the cycle form the alternative solution.

The two main safety valves incorporated in the system (not shown), are contained in the main pressure supply line to the auxiliary pressure vessel and they are set to operate at 210 lb per square inch and 220 lb per square inch respectively.

*Torque Load.*—An appreciation of the design of polyzonal spiral fuel elements, reference 5, suggests the necessity of having to apply torque to the elements under test because of the aerodynamic gas loads. In a fuel channel the top or bottom element has to react the cumulative aerodynamic torque offered by all the other elements; the ends of elements of this type must therefore be arranged so as to interlock in a simple manner. The first fuel element meeting the gas flow in a channel experiences a higher individual torque than the remainder of the elements since it imparts the initial rotational motion to the gas; in fact it acts as a preswirler. A separate preswirler would probably reduce the overall torque reaction by an appreciable amount.

Fig. 9, which is virtually self-explanatory, shows a projected design for applying torque over a limited angular range using bellows of similar dimensions and characteristics to those incorporated in the device for applying end load. The assembly is mounted on a plate sandwiched between the bottom flange of the main pressure vessel and the top flange of the auxiliary vessel. The bellows are subjected to an external pressure of 200 lb per square inch at all times. It will be remembered that the main supply pressure is taken initially to the auxiliary vessel and thence to the main vessel by holes drilled in the fuel element support plate; these holes are not shown in the diagram.

One end of each of the bellows is attached to small fixed fittings containing passages for the supply of $CO_2$ to the inside of the bellows. The other ends of the bellows which terminate in a single lug are pinned to lever arms mounted on two shafts. The shafts also carry segmental gears which in turn drive a common central gear and via a shaft, the fuel element support.

A torque reaction support of some kind must of course be provided at the top of the fuel element. For this reason the simultaneous application of end load and torque would appear to involve mechanical complications but should not be impossible.

In the system described no special facilities are provided for compensating the spring stiffness of the bellows shown here in their extended position; however, the geometry of the design can be arranged such that, as the internal pressure in the bellows is reduced to below 200 lb per square inch, the bellows contract and the length of the lever arm driving the segmental gears becomes effectively longer and hence the reduction in

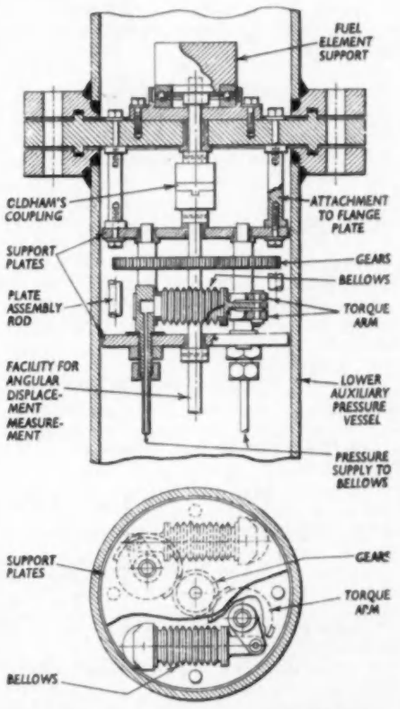


**Fig. 9—Schematic layout of proposed bellows design for applying torque load to a fuel element**

effort brought about by the spring stiffness of the bellows is offset to some extent.

For zero torque conditions the internal pressure applied to the bellows is held at approximately 200 lb per square inch and for maximum torque is reduced to atmospheric pressure. The simple coupling shown in the diagram is merely provided to facilitate assembly.


## Acknowledgments

The author wishes to thank Atomic Power Constructions, Ltd., for its kind permission to publish this paper and to acknowledge the design studies, theoretical calculations, and contribution of numerous ideas advanced by members of the group who were associated with the project.


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## APPENDIX I

### Theoretical Analysis of Design for Applying End Load to Fuel Elements†

A line diagram of the compensating system is given in Fig. 10. The central shaft applies an end load to the fuel element derived from pressure acting on the bellows. As conditions in the thermal cycling rig change, the loading head, and hence shaft, can move vertically by the maximum

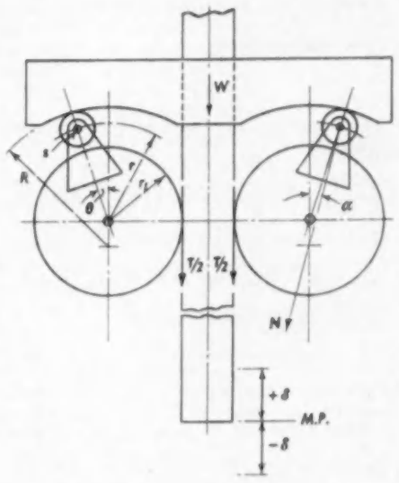


**Fig. 10—Line diagram and notation for bellows compensating system**

amount $\pm\delta$, where $\delta=\frac{1}{4}$in. When this occurs the bellows, owing to their spring stiffness, apply an additional load of up to ±40 lb to the shaft. To maintain the algebraic sum of the loads on the shaft at a constant value the load contribution offered by the bellows must be eliminated. The device shown in the diagram can achieve this purpose provided suitable dimensions are chosen for the component parts.

Assume that the gearwheels and rollers are weightless and have frictionless bearings. Then $N$ acts along the normal to the curved surface of $W$ at the point of contact of $W$ with the roller. The spring rate of the bellows

$$=\frac{40}{0{\cdot}75}\ \text{lb/in}=53{\cdot}30\ \text{lb/in}$$

so that

$$S=53{\cdot}30\,.\,\delta \qquad . \ . \ . \ . \ . \ (1)$$

When, for example, the shaft moves up, the bellows apply a downward force to the shaft. The system adopts the configuration shown in the diagram, the reactions $N$ apply a moment to the gearwheels and thereby introduce a restoring force $T$ on the shaft to

† *Notation*

$r_1$—Effective radius of each gear wheel (in).
$s$—Radius of each roller (in).
$r$—Radius of action of centre of roller (in).
$R$—Radius of circular arc in base of weight carrier (in).
$\delta$—Displacement of shaft (in).
$\theta$—Angle of rotation of gear wheel (radians).
$\alpha$—Angle between vertical and normal at point of contact of the roller and the weight carrier.
$W$—Weight (lb) (total of weight and weight carrier).
$N$—Reaction on gearwheel due to the weight (lb).
$T$—Force on shaft to balance the reactions $N$ (lb).
$S$—Reaction of bellows on shaft when shaft displacment is $\delta$.

compensate for the force applied by the bellows.

It is required to find $W$, $r_1$, $r$, $s$, and $R$, so that $T$ is as nearly equal to $S$ as possible for all values of $\delta$ up to the maximum of $\delta = \pm 0{\cdot}75$in.

The overall dimensions of the device, and in particular $r_1$, have to be made as small as possible.

*Calculation of $W$, $r_1$, $r$, $s$, $R$.*—We have

$$\delta = r_1\theta \quad . \quad . \quad . \quad . \quad . \quad (2)$$

giving

$$S = 53{\cdot}30 \, . \, r_1 \, . \, \theta \quad . \quad . \quad . \quad (3)$$

Resolving vertically,

$$N = \tfrac{1}{2} \, . \, W \, . \, \sec . \, \alpha \quad . \quad . \quad (4)$$

The total turning moment on the two gearwheels

$$= 2 \, . \, N \, . \, r \, . \, \sin(\theta - \alpha) = W \, . \, r \, . \, \sec . \, \alpha \sin(\theta - \alpha)$$

This is balanced by a moment $Tr_1$ and

$$Tr_1 = W \, . \, r \, . \, \sec . \, \alpha \sin(\theta - \alpha) \quad . \quad (5)$$

From the geometry, putting

$$R - s = t, \text{ and, } r/t = V \quad . \quad . \quad . \quad . \quad (6)$$

we obtain

$$t \, . \, \sin . \, \alpha = r \, . \, \sin . \, \theta \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Equations (5), (6), and (7), give

$$T = W \, . \, \frac{r}{r_1} \, . \, \sin\theta \left(1 - \frac{V \, . \cos . \, \theta}{\sqrt{1 - V^2 \sin^2\theta}}\right)$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Comparing equations (3) and (8), since $T$ and $S$ must be made as nearly equal as possible, $V$ must be chosen such that

$$x = \sin . \, \theta \left(1 - \frac{V \, . \cos . \, \theta}{\sqrt{1 - V^2 \sin^2\theta}}\right)$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (9)$$

is as nearly proportional to $\theta$ as possible.

Table I lists values of $x$ for $\theta$ from 0 deg. to 70 deg. for different values of $V$.

To consider the suitability of these values of $x$ we fit a line

$$x = b \, . \, \theta \quad . \quad . \quad . \quad . \quad . \quad (10)$$

to the values of $x$ for a given value of $\theta$.

By inspection the most linear values of $x$ are within the range $V = 0{\cdot}30$ to $V = 0{\cdot}34$.

Linearity is very good up to $\theta = 50$ deg., but falls off between 50 deg. and 70 deg. with increasing rapidity.

In order to keep the value of $r_1$ as small as possible it is necessary to work over the whole range of $\theta$ given above otherwise a range of $0 < \theta < 50$ deg. would be preferable.

In equation (10) $b$ can be chosen either to minimise the r.m.s. error or to minimise the maximum error between the actual curve and the fitted values given by equation (10).

Let given value of $x$ for $\theta = \theta_i = x'_i$ as in the table, and let the calculated value of $x$ for $\theta = \theta_i = x_i$, as given by equation (10).

(i) Value of $b$ by method of least squares.

By trial and error, the minimum r.m.s. error occurs when $V = 3{\cdot}30$ ($0 \leqslant \theta \leqslant 70$ deg.).

Mean square error

$$= \frac{1}{14} \cdot \sum_{i=1}^{14} (x'_i - x_i)^2$$

$$= \frac{1}{14} \cdot \sum_{i=1}^{14} (x'_i - b\theta_i)^2 \, . \quad . \quad . \quad (11)$$

This is a minimum for $b$ when

$$\sum_{i=1}^{14} \theta_i \, . \, (x'_i - b\theta_i) = 0 \quad . \quad . \quad (12)$$

Measuring $\theta$ in degrees, this gives,

$$25375 \, b = 302{\cdot}16$$
$$b = 0{\cdot}01190$$
$$x = 0{\cdot}01190 \, . \, \theta \quad (\theta \text{ in degrees})$$

or,

$$x = 0{\cdot}68187 \, . \, \theta \quad (\theta \text{ in radians})$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (13)$$

For this value of $b$, r.m.s. value of the error

$$(x'_i - x_i) = 0{\cdot}0025$$

and the maximum value of the error

$$= -0{\cdot}0049$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (14)$$

(ii) To minimise the maximum value of the error $(x'_i - x_i)$.

By trial and error the best value of $V$ is found to be 0·34.

Then by trial and error,

$$b = 0{\cdot}01180$$
$$x = 0{\cdot}01180 \, . \, \theta \, (\theta \text{ in degrees})$$

or

$$x = 0{\cdot}67614 \, . \, \theta \, (\theta \text{ in radians})$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (15)$$

For this value of $b$, the r.m.s. value of the error

$$(x'_i - x_i) = 0{\cdot}0029$$

and the maximum value of the error

$$= -0{\cdot}0040$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (16)$$

(iii) If $\theta$ is restricted to $0 \leqslant \theta \leqslant 65$ deg., even better accuracy can be obtained by taking $V = 0{\cdot}32$.

One value of $b$ minimises both maximum $(x'_i - x_i)$ and r.m.s. $(x'_i - x_i)$.

This is

$$b = 0{\cdot}01202$$

giving

$$x = 0{\cdot}01202 \, . \, \theta \, (\theta \text{ in degrees})$$

or,

$$x = 0{\cdot}68875 \, . \, \theta \, (\theta \text{ in radians})$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (17)$$

The r.m.s. value of the error

$$(x'_i - x_i) = 0{\cdot}0017$$

and the maximum value of the error

$$= -0{\cdot}0028$$

$$. \quad . \quad . \quad . \quad . \quad . \quad (18)$$

*The determination of Practical Values of $W$, $r_1$, $r$, $s$, $R$.*—Choose $0 \leqslant \theta \leqslant 70$ deg. and take

$$V = 0{\cdot}34 \quad . \quad . \quad . \quad . \quad . \quad (19)$$

to minimise the maximum error $(x'_i - x_i)$, approximately

$$T = \frac{W \, . \, r}{r_1} \, . \, b \, . \, \theta$$

$$= \frac{W \, . \, r}{r_1} \, . \times 0{\cdot}67614 \, . \, \theta \quad . \quad (20)$$

where $\theta$ is in radians.

This value of $T$ must balance $S$, giving

$$\frac{W \, . \, r}{r_1} \, . \times 0{\cdot}67614 \, . \, \theta = 53{\cdot}30 \, . \, r_1 \, . \, \theta \quad (21)$$

The maximum values of the r.h.s. of equation (21) is 40 lb when $\theta = 70$ deg. when

$$70 \, . \, r_1 = 57{\cdot}30 \times 0{\cdot}75$$
$$r_1 = 0{\cdot}6140 \quad . \quad . \quad (22)$$

Now values of $r_1$, $R$, and $s$ can vary by steps of $\frac{1}{16}$in, $\frac{1}{8}$in, and $\frac{1}{16}$in, respectively (say), whereas any value can be chosen for $r$.

As long as $r_1 \geqslant 0{\cdot}6140$, $\theta$ will lie in $<0, 70,>$

Therefore choose

$$r_1 = 0{\cdot}625\text{in, i.e. } (\tfrac{5}{8}\text{in}) \quad . \quad (23)$$

Therefore by equation (21)

$$Wr = 30{\cdot}79 \quad . \quad . \quad . \quad . \quad (24)$$

Also, $V = r/(R - s) = 0{\cdot}34$.

Since it is desirable to make $r$ as small as possible let us choose

$$s = \tfrac{1}{2}\text{in} \quad . \quad . \quad . \quad . \quad (25)$$

Some choices for the values of the parameters are listed in Table II, these demand a rather different mechanical layout to that shown in Fig. 7, but many other combinations of values are possible.

TABLE I—*Values of x for Various Values of θ and V*

| θ deg. | V = 0·2 | 0·3 | 0·32 | 0·33 | 0·34 | 0·36 | 0·38 | 0·40 | 0·50 |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 0·0698 | 0·0611 | 0·0594 | 0·0585 | 0·0576 | 0·0559 | 0·0542 | 0·0542 | 0·0437 |
| 10 | 0·1395 | 0·1223 | 0·1189 | 0·1172 | 0·1154 | 0·1120 | 0·1086 | 0·1051 | 0·0878 |
| 15 | 0·2087 | 0·1836 | 0·1785 | 0·1760 | 0·1735 | 0·1684 | 0·1634 | 0·1583 | 0·1328 |
| 20 | 0·2776 | 0·2451 | 0·2385 | 0·2353 | 0·2320 | 0·2254 | 0·2188 | 0·2122 | 0·1789 |
| 25 | 0·3457 | 0·3068 | 0·2989 | 0·2950 | 0·2910 | 0·2831 | 0·2752 | 0·2672 | 0·2267 |
| 30 | 0·4130 | 0·3686 | 0·3597 | 0·3551 | 0·3506 | 0·3416 | 0·3324 | 0·3233 | 0·2764 |
| 35 | 0·4790 | 0·4305 | 0·4207 | 0·4157 | 0·4108 | 0·4007 | 0·3907 | 0·3805 | 0·3284 |
| 40 | 0·5435 | 0·4923 | 0·4818 | 0·4765 | 0·4712 | 0·4606 | 0·4489 | 0·4390 | 0·3828 |
| 45 | 0·6061 | 0·5536 | 0·5428 | 0·5374 | 0·5320 | 0·5210 | 0·5098 | 0·4986 | 0·4398 |
| 50 | 0·6663 | 0·6143 | 0·6035 | 0·5981 | 0·5926 | 0·5816 | 0·5704 | 0·5591 | 0·4995 |
| 55 | 0·7238 | 0·6737 | 0·6633 | 0·6581 | 0·6527 | 0·6421 | 0·6312 | 0·6202 | 0·5616 |
| 60 | 0·7781 | 0·7315 | 0·7218 | 0·7169 | 0·7119 | 0·7020 | 0·6918 | 0·6814 | 0·6259 |
| 65 | 0·8284 | 0·7869 | 0·7785 | 0·7739 | 0·7694 | 0·7605 | 0·7512 | 0·7419 | 0·6915 |
| 70 | 0·8743 | 0·8392 | 0·8319 | 0·8281 | 0·8244 | 0·8168 | 0·8090 | 0·8101 | 0·7577 |

TABLE II—*Possible Choice for Parameters $r_1$, $r$, $s$, $R$, $W$*

| Parameter | Possible choice | | |
|---|---|---|---|
| $r_1$ ... ... ... ... | 0·625in | 0·625in | 0·625in |
| $r$ ... ... ... ... | 0·680in | 0·595in | 0·510in |
| $s$ ... ... ... ... | 0·500in | 0·500in | 0·500in |
| $R$ ... ... ... ... | 2·50in | 2·25in | 2·0in |
| $W$ ... ... ... ... | 45·28 lb | 51·74 lb | 60·37 lb |

# Edge Cracking of a Steel Band Conveyor

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*Two experimental rubber-covered steel-band conveyors were installed in British coal-mines. A chance inspection of a butt joint, after a period of fairly successful operations, revealed cracks in the edges of the steel band. Further cracks along the conveyor band were detected by means of a special electronic device without the need to remove the rubber covering. A stress analysis of the conveyor installation pointed to the fixed wing troughing rollers as the cause of failure. Strain-gauge measurements* in situ *confirmed this diagnosis, and the trouble was virtually cured by the installation of articulated rollers. Continued fault-free service of this type of conveyor requires more nearly ideal working conditions than are needed for flexible belt conveyors.*

PROMPTED by the need for heavy-duty conveyors, capable of carrying large loads over great distances and up considerable gradients, the Production Department of the National Coal Board decided, in 1956, to try out two steel band conveyors in coal-mines. This type of conveyor combines the strength of a steel band with the abrasion-resistant properties of rubber covering. One of these experimental units, 558 yards long of 31½in wide band, was installed in a steep drift (1 in 3½) at Reedley Colliery, Lancs. After a period of successful operation one of the jointed sections was uncovered for inspection and a number of cracks at the edges of the band and the butt-strap were discovered. Further examination confirmed the existence of cracks at other positions of the band. The dangers of multiplication and growth of such cracks are obvious. Methods for detecting the cracks without the removal of the rubber covering, investigation of the causes of failure and advice on steps to cure the malady were sought from the Mining Research Establishment, at Isleworth.

## Crack Detection

In order to observe the growth of the cracks in the band, and to examine the whole of the band for further cracks, equipment was developed at the Mining Research Establishment, Isleworth, which could indicate the position and the extent of the cracks, without the need for removing the rubber covering of the band. The equipment makes use of the electromagnetic properties of steel. When a coil carrying alternating electric current is brought near to a conducting material, eddy currents are induced in the material by the changing magnetic field of the coil. These currents produce their own field which tends to neutralise and prevent the penetration of the primary field into the material. The magnitude of the eddy currents and the depth to which they and the primary field penetrate depend on the geometry of the system, on the frequency of the primary current and on the permeability and resisitivity of the material involved. This effect is entirely independent of any intermediate non-conducting materials, such as the rubber covering of the steel band.

When such a coil, carrying current alternating at, say, 10 kc/s, is brought near to one side of a steel band, the eddy currents produced are sufficient to prevent penetration of the field to more than about 0·5mm. A crack in the band, however, impedes these eddy currents and permits the primary field completely to penetrate the band. A search coil, placed on the opposite side of the band, will then produce a voltage which may be used to indicate the presence of a crack.§ An alternative and more sensitive method of detecting changes in the eddy current pattern (caused by cracks) is to place search and field coils on the same side of the band and observe the magnitude and phase of the voltage induced into the search coil by the eddy currents. In this case, however, the coils must be critically placed relative to each other so that no secondary voltage is induced by the primary current. This can be achieved by overlapping the coils (cross coil arrangement).

In the first, or "screened," system the output from the search coil was taken to an amplifier and then to an electronic trigger unit. This unit controlled an alarm bell and a paint spray gun. When the output from the search coil rose (indicating a flaw) the trigger operated, rang the bell and caused a jet of paint to be sprayed on to the belt so that the position of the flaw could be found later when the belt was stationary. Adjustments were provided to set the level at which the trigger would operate and to alter the duration of the alarm pulse.

Each type of coil arrangement has certain advantages in a practical application, and both were used in the surveys of the band at Reedley. The screened coil arrangement was ideally suited for scanning the band when running at normal speed. It was unsuitable, however, where two thicknesses of steel were present (for example at a joint) since if one sheet was cracked the second sheet still maintained its full screening power.

The crossed coil arrangement observed the eddy currents in the surface of the sheet adjacent to it and could therefore be used at joints where two thicknesses of sheet were present.

Details of the design and construction of the equipment actually used will be published later. A typical distribution of flaws in the belt loop as illustrated in Figs. 1 and 2 shows the shapes of cracks at the edge of an uncovered length of band.

## Stress Analysis

An inspection was made over the length of the installation. The conveyor had been accurately aligned, little wear was noticeable on the self-aligning rollers and no significant vibration could be detected at the idler roller supports. The conveyor band, 31½in in width, was composite in structure, consisting sectionally of a 1·2mm steel band with 5mm top and 2mm bottom rubber coverings. Butt straps were used to join separate length of 100 yards to 180 yards (see Fig. 3). The drive unit comprised a 120 h.p. motor coupled to a 50in driving drum, giving the band a linear speed of 250ft per minute. The 40in tail drum was tensioned through a double purchase system by 2000 lb ballast weights. The direct longitudinal tensile stress in the steel band resulting from driving and pretensioning was estimated to equal 8400 lb per square inch.

Flexure of a band introduces complementary tensile and compressive stresses which are highest at the outermost fibres. For simple bending the neutral axis can be assumed to pass through the centroid of the section of the band and it can be shown that the intensity of stress in the outer fibres

$$= \frac{(\text{Thickness of steel band}).\ E}{2\ (\text{Radius of bending})},$$

where $E$ = Youngs Modulus of Elasticity of the steel.

The variation of maximum fibre stress with radius of bending of the steel band is shown in Fig. 4.

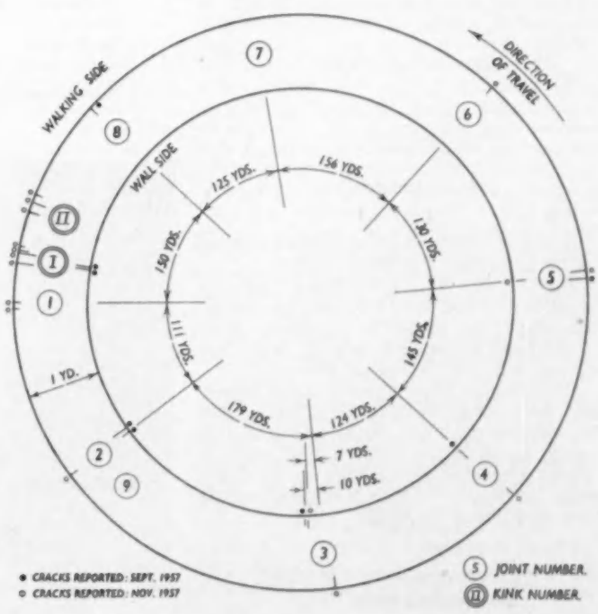


**Fig. 1 — Diagrammatic sketch of steel band conveyor belt showing positions of joints and fractures**

§ Terman. *Radio Engineering Handbook*, first edition, McGraw-Hill, 1950, page 130.

* Now with Central Electricity Generating Board.
† Now Mechanical Engineering Adviser, Process Development Department, National Coal Board.
‡ Mining Research Establishment, National Coal Board.

Fig. 2—Cracks along edge of steel band

Tracings were taken of the edge of the conveyor band lying over a number of the idler rollers by resting pieces of cardboard on the rollers. The curvature of the edge of the band when passing over the first troughing roller before the drive head, indicated quite a sharp change in slope (Fig. 5). Assuming that a short length of band $L$ acts like a simply supported beam with a centrally applied single load $W$ it can be shown that the change in slope $\theta$, over the length $L$ of the beam is

$$= \frac{\text{Area of bending moment diagram}}{EI};$$

i.e.

$$\theta = \frac{WL^2}{8EI}; \text{ and } W = \frac{8EI\theta}{L^2}$$

Bending stress at outer fibre,

$$= \frac{\text{Bending moment} \times \text{Dist. of outer fibres from neutral axis}}{I}$$

therefore,

$$f = \frac{WLy}{4I} = \frac{2Ey\theta}{L}.$$

Substituting values measured from Fig. 5, we obtained $f$=27,000 lb per square inch.

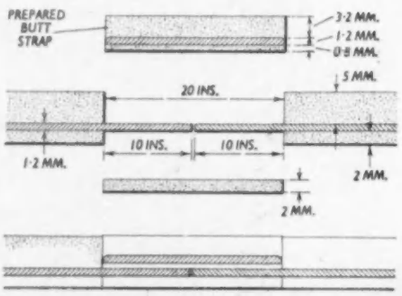


Fig. 3—Butt strap joint

It can be shown that the effective bending radius to produce this stress = 26·1in.

The first (or No. 1) troughing roller was installed 5ft from the driving drum. Within this length the transverse troughing radius of the band increased to infinity as the belt ran on to the flat face of the drum.

Providing no buckling occurs, and assuming the change of troughing takes place between the roller and the driving drum, the tensile stress in the edges can be approximately evaluated by calculating the differential longitudinal stretch between the centre and the edges of the band.

If

$z$ = extension of band at edges

$x$ = troughing depth

then

$$z = (60^2 + x^2)^{\frac{1}{2}} - 60$$

or

$$z \simeq 60\left[1 + \frac{1}{2}\left(\frac{x}{60}\right)^2\right] - 60$$

Therefore, the change in length $= \frac{1}{2}\left(\frac{x}{60}\right)^2$

$$= \text{strain, and stress} = \frac{E}{2} \cdot \left(\frac{x}{60}\right)^2 = 4165\,x^2.$$

Fig. 6 shows the variation of tensile stress in the outer edges of the steel band with different troughing depths. The maximum troughing depth of the No. 1 roller was calculated by assuming that the band made tangential contact with the rollers at its edges and centre position. (Type A troughing roller was used on the installation, see Fig. 7). The value obtained, 0·965in, is shown superimposed on graph (Fig. 6).

Bubbles found between the rubber covering and the steel band, about 3in from the edge, aroused the suspicion that high local stresses might exist at the juncture of the wing and centre rollers. In an endless belt, flexing in several directions, a complex system of stresses is set up. If, however, a simplified model is considered which errs well on the

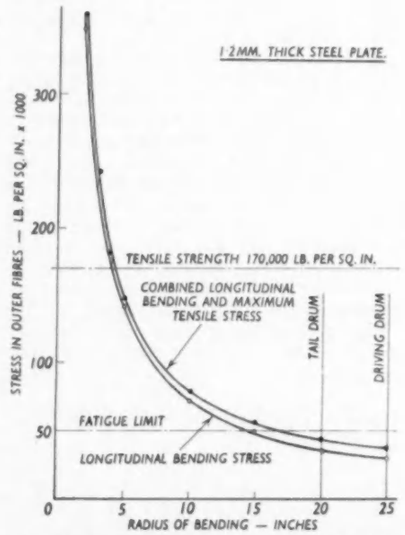


Fig. 4—Variation of fibre stress with radius of bending

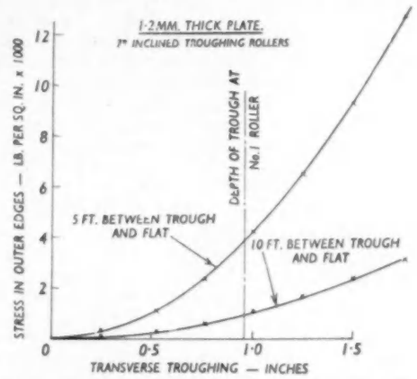


Fig. 6—Variation of tensile stress with change of transverse troughing

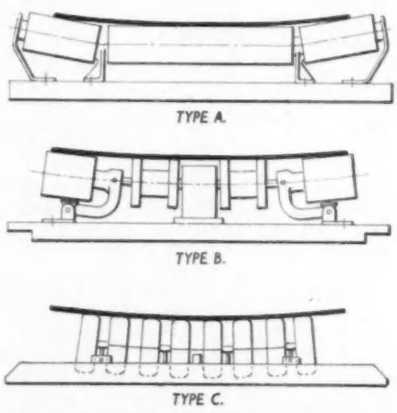


Fig. 7—Troughing rollers for steel band conveyor

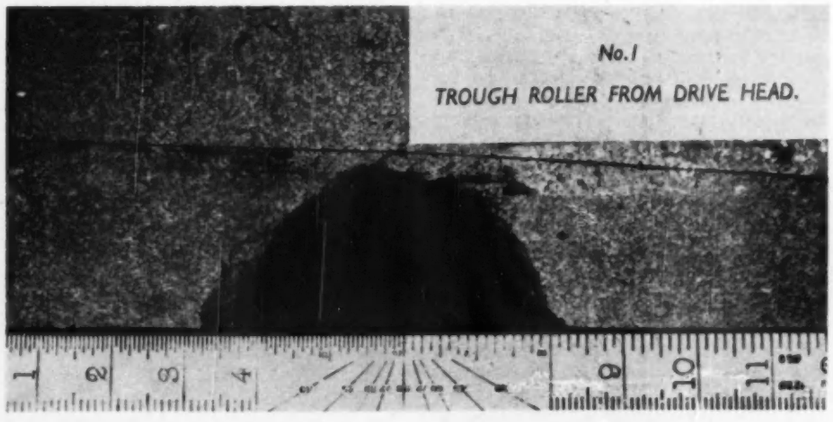


Fig. 5—Trace of band edge on troughing roller

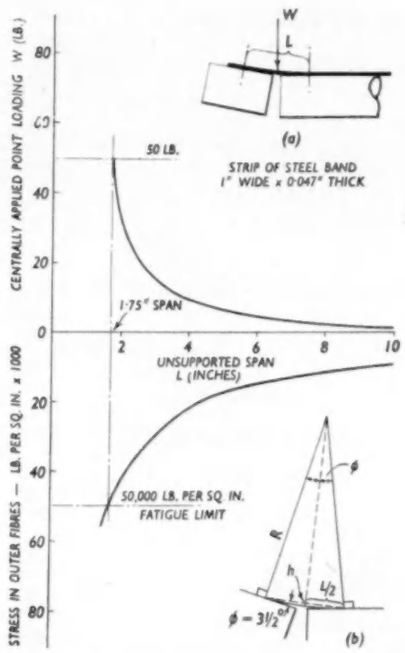


Fig. 8—Load and stress due to transverse troughing

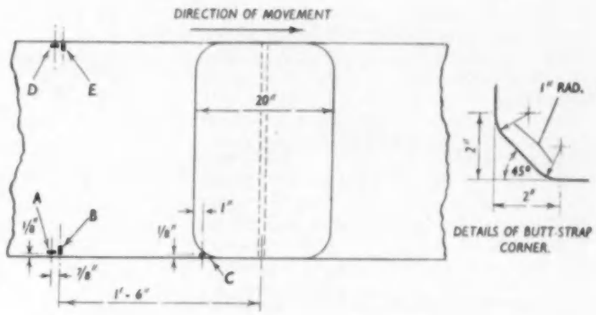


Fig. 9 — Distribution of strain gauges on and near butt-strap

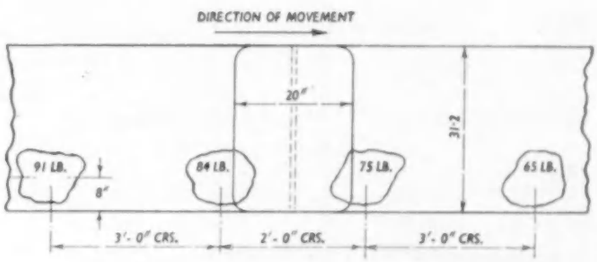


Fig. 10 — Positions of stones over instrumentated section of band

conservative side of the real situation, an idea may be gained of the magnitude of stress that can be expected. Consider a 1in wide transverse strip of belt resting on the troughing rollers. What local load would be required to bend this strip down the wing roller to produce a fibre stress of 50,000 lb per square inch, i.e., the fatigue limit ?

From Fig 8 (*a*) and (*b*), we have

$$R=\frac{L^2}{4h}+h,$$

and also

$$h=R(1-\cos\phi),$$

which, combined, give

$$R=L\cdot\sqrt{\frac{1}{4(1-\cos^2\phi)}}$$

Substituting $\phi=3\frac{1}{2}$ deg. (troughing angle =7 deg.), we get $R=8\cdot11\ L$.

For a simply supported beam, centrally loaded, we have

$$\frac{WL}{4I}=\frac{E}{R},$$

Therefore

$$W=\frac{4EI}{8\cdot11L^2}$$

Substituting the appropriate values for $E$ and $I$, we obtain $W=128/L^2$.

In Fig. 8 the relationship between $W$ and $L$ is shown, together with a curve of stress similar to Fig. 4. From these it can be seen that a point loading of 50 lb would be required to produce a fibre stress of 50,000 lb per square inch in a 1in wide strip of steel band. For a 10in wide strip the corresponding load would be 500 lb. Boulders of rock exceeding 100 lb would not normally be carried on this conveyor and hence stresses due to transverse bending could be considered negligible.

From examination of Figs. 4, 6 and 8 it appears that the most damaging form of stress arose from longitudinal bending of the steel band over the troughing rollers. As an illustration of this, a combined longitudinal bending and tensile stress curve is added to Fig. 4, together with the quoted values of maximum tensile strength and fatigue limit for the band steel.

The trace obtained at No. 1 troughing roller showed a bending radius of approximately 26in over a short length. This effect, together with the tensile stresses due to the change in troughing form, the drive tension, and pre-tensioning, was estimated to produce a tensile stress within the band edges of the order of 40,000 lb per square inch. The trace was obtained when the band was running lightly loaded. It was considered reasonable to expect that with heavy loading conditions, the contact radius of the band over the troughing rollers would be further reduced, resulting in higher values of bending stress. Stresses arising from change in troughing shape and transverse bending over troughing rollers, appeared to be comparatively low, as would also be expected of the stresses resulting from longitudinal and transverse shear.

The distribution of the cracks suggested that the relative stiffness of the joints had tended to concentrate the flexing of the band near the joint edges, and, furthermore, that unless each butt strap was correctly aligned, there would be a tendency for an uneven pull to develop, resulting in higher stresses on one side of the belt. This examination gave reasonable cause to suspect that dangerous combined tensile and bending stresses might well occur at the edges of the steel band, particularly at the sudden changes in cross section existing at the butt strap joints. As a result, it was decided to set up equipment to measure the actual stresses involved and, in addition, to study the influence of roller design.

## Stress Measurements

For the purpose of examination three selected types of troughing roller (see Fig. 7) featuring a standard fixed wing and two forms of articulated constructions, were positioned in neighbouring groups of six immediately downstream of the conveyor drive head. An undamaged butt joint was uncovered and strain gauges attached to the steel band in positions designed to afford an overall assessment of the major stress variations in or near to the joint (Fig. 9). The rubber covering was replaced and vulcanised. The butt strap was driven round to the tail drum and, once past the drum, coal was loaded on to the conveyor band. Loading of coal continued until the butt strap was arrested approximately 20 yards before the test zone. Four large stones were weighted on, and spaced about the butt strap at distances of 3ft, 2ft and 3ft apart, and as near to the walking side edge of the band as possible (Fig. 10). Due clearance was left to avoid contact with occasional self-aligning side rollers. A multi-core cable was paid out over the driving drum, laid on the top strand of the conveyor and ended in a plugged connection to the strain gauge leads. The conveyor was started and run up to full speed, the loaded butt strap passing rapidly over successive groups of test rollers and finally on to the driving drum. As the butt strap passed around the drum, the cable, which had been progressively reeled in by hand, was jerked out of the plug, and the conveyor drive switched off.

A filmed record was made of the changes in resistance of the electric strain gauges. The record consisted of five continuous traces with pronounced peaks at regular intervals, representing the strains due to bending over each troughing roller. The vertical displacement of each trace from a previously established base line corresponded to a certain value of tensile or compressive strain. A conversion factor was determined for each gauge employed and in this manner it was possible to convert directly a trace ordinate to a value of stress in pounds per square inch. To afford easy comparison, the stress variations over each type of troughing roller are shown grouped separately for each gauge (Figs. 11 to 15).

The strain gauges were balanced prior to the commencement of the experimental run and hence did not record any initial tension in the steel band. To estimate the maximum stresses within the band, it was necessary to include the pretensioning load of 2000 lb, and to approximate the tensile stress caused by the weight of carried coal acting down the gradient of the conveyor. A triangular distribution of load was assumed across the width of the belt with a maximum depth of 8in of coal at the centre. Taking the density of run-of-mine coal as 50 lb per cubic foot,

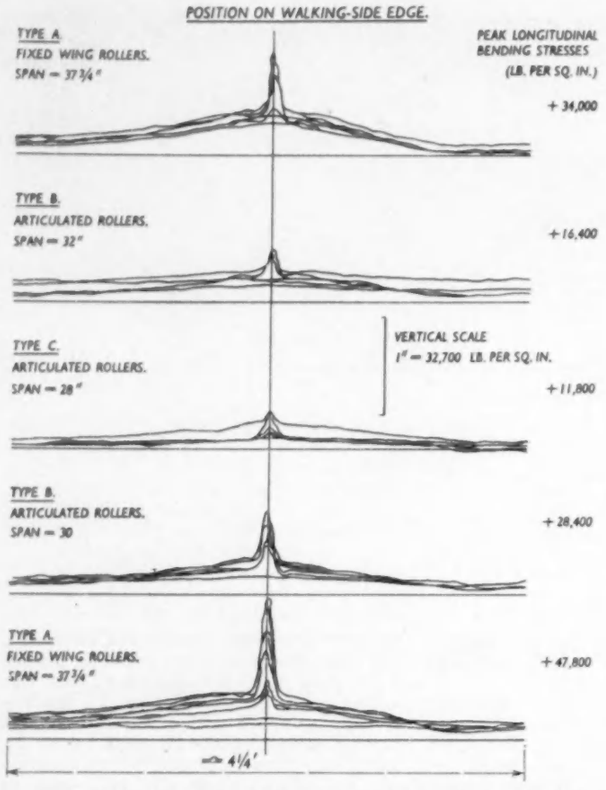


**Fig. 11—Longitudinal stress records for gauge *A*—band passing over troughing rollers**

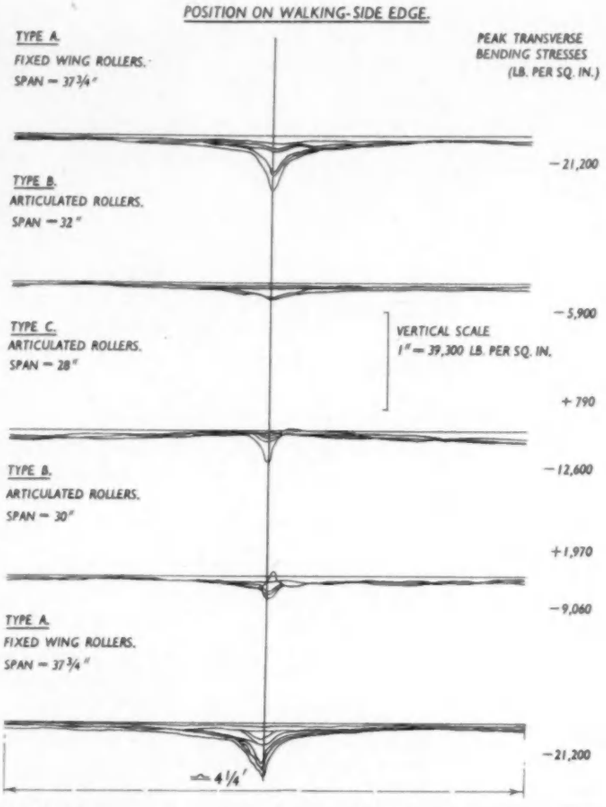


**Fig. 12—Transverse stress records for gauge *B*—band passing over troughing rollers**

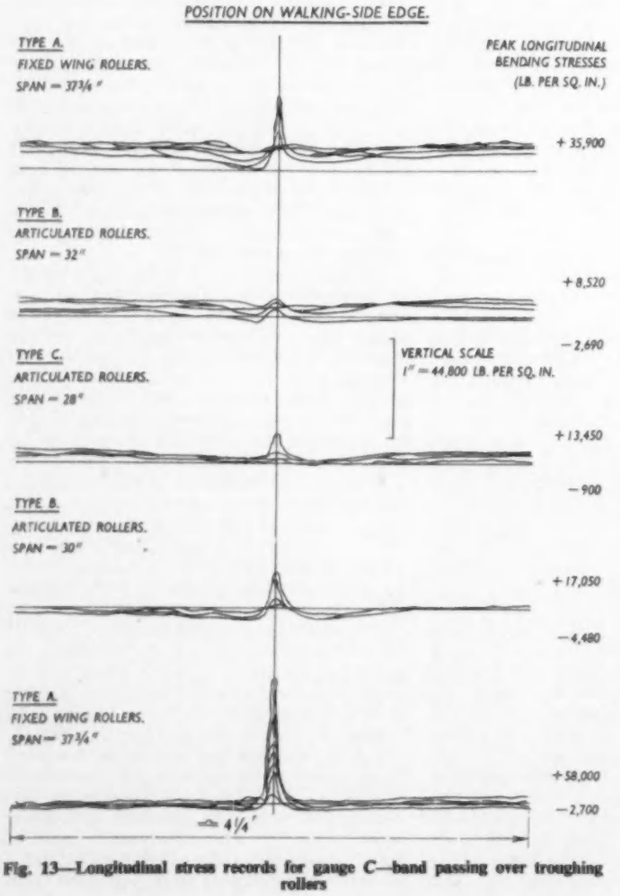


**Fig. 13—Longitudinal stress records for gauge *C*—band passing over troughing rollers**

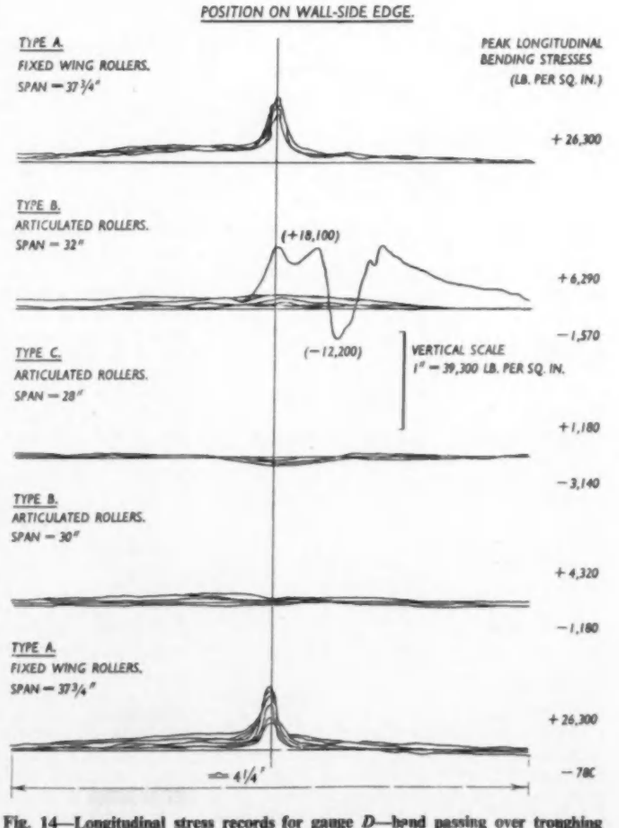


**Fig. 14—Longitudinal stress records for gauge *D*—band passing over troughing rollers**

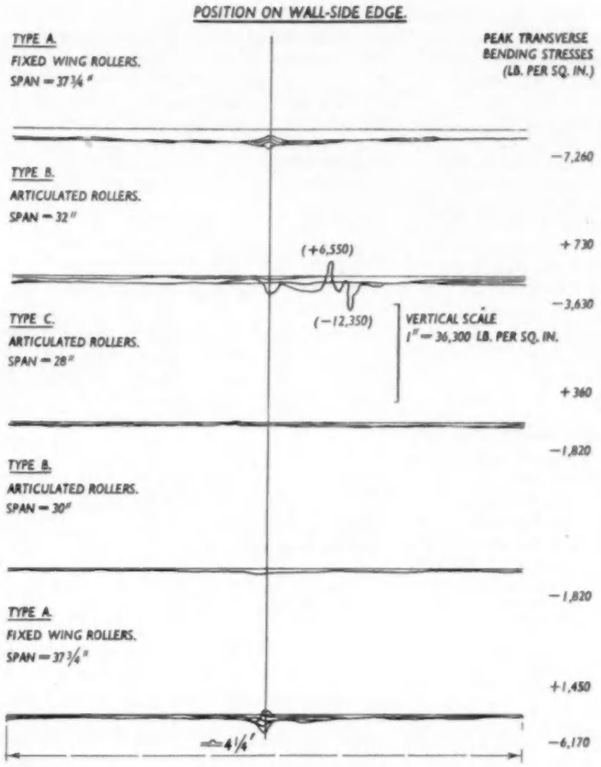


Fig. 15—Transverse stress records for gauge *E*—band passing over troughing rollers

and the length of loaded belt as equal to 500 yards, the tensile stress was due to the weight of carried material and initial pretensioning was estimated to be 13,300 lb per square inch.

Fig. 16 depicts the variation in stress in the outer fibres due to the bending of the band as it was drawn on to the drum. In general, the gauges recording longitudinal tensile stress indicated fairly sharp increases

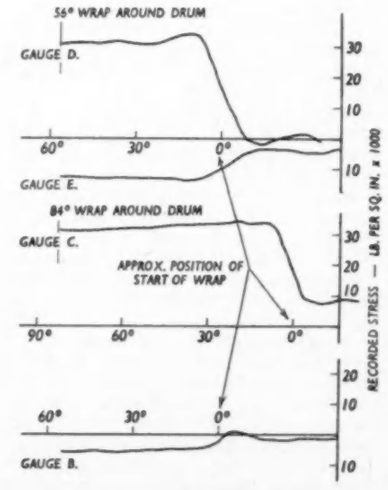


Fig. 16—Recorded longitudinal and transverse stresses—band passing over driving drum

in value from, in some cases, a negative (i.e. compressive) figure. The maximum tensile value achieved, then progressively decreased as the angle of wrap of the band round the drum increased beyond 20 deg. The calculated value of tensile stress, produced by bending the band around the 50in diameter driving drum has been estimated in the earlier examination to equal 28,200 lb per square inch. The peak values of stress recorded by gauges *C* and *D* reached 34,100 lb and 33,500 lb per square inch respectively; the increased values arose, most likely from the additional tensile forces required to overcome dynamic resistance within the conveyor installation. These forces were not included in the stationary "balancing" of the gauges. Reduction of the tensile stresses to approximately 31,000 lb per square inch is illustrated on the recordings taken from gauges *C* and *D*. The compressive stress, recorded by gauges *B* and *E* was probably a Poisson's Ratio effect, the applied driving tension producing a transverse compression strain.

The position of a gauge in relation to the butt strap evidently influenced the recorded variations of the stress over a given type of troughing roller. Fig. 13, which shows the average variation of stress recorded by gauge *C* (positioned close to the edge of the butt strap) over each test group of rollers, indicates that there was a tendency to produce a small initial compression in the outer fibres of the steel band just before, and after, contact with a troughing roller. This characteristic was not reflected by the gauges positioned further away from the joint. The supposition is that the compressive stresses recorded by gauge *C* were due to the constraining effect of the butt strap, compared to the resilience of a normal length of steel band. As the stiff butt strap passed over the small diameter rollers, the trailing length of belting was subjected to reversed bending, as illustrated diagrammatically on Fig. 17. This effect was accentuated by the 84 lb rock placed near to the walking edge, with its centre of gravity approximately 2in away from the trailing edge of the butt strap.

Both gauges *A* and *D*, which were unaffected by the stiffness of the butt strap, gave records of gradual increase in tensile stress, a sharp peak above the rollers and then again a slow fall-off in stress values. The initial progressive increases in stress was more apparent in gauge *A* due to the localised action of two of the heavy rocks, weighing approximately 85 lb to 90 lb, placed along the walking side edge (Fig. 10). Figs. 12 and 15 record the complementary variation in transverse compressive stress produced by the troughing action over the roller sets. Together with the variations of tensile stress shown in Figs. 11, 13 and 14, they provide conclusive evidence of the advantageous performance of the articulated form of roller.

Along the rock-loaded walking side edge, the average figures of bending stress, obtained when passing over the 32in- and 30in-span,

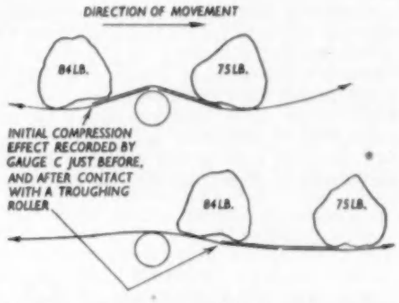
DIRECTION OF MOVEMENT
84 LB.
75 LB.
INITIAL COMPRESSION EFFECT RECORDED BY GAUGE C JUST BEFORE, AND AFTER CONTACT WITH A TROUGHING ROLLER
84 LB.
75 LB.

Fig. 17—Suggested flexure of butt strap passing over troughing roller, illustrating possible source of compressive stress recorded at gauge *C*

type B articulated and type C articulated rollers amounted to 32, 59 and 27 per cent respectively of the average stress values recorded across the standard fixed wing roller. On the lightly loaded wall side edge of the band, the 32in and 30in, type B, articulated rollers caused stresses equalling 18 and 7 per cent respectively of the equivalent average bending stress figures recorded over the fixed wing (type A), troughing roller. In this instance, no positive figures of bending stress were obtained when passing over a type C articulated troughing unit. For the two extremes of loading it is apparent that the articulated forms of troughing roller appreciably reduced the bending stresses, type C appearing to be the most effective.

Figures of the fatigue limit and ultimate tensile strength of the steel utilised in constructing the conveyor band were quoted as 50,000 lb per square inch and 170,000 lb per square inch respectively. The limit of fatigue strength signifies that with a zero static tensile stress, the maximum range of stress is limited to 100,000 lb per square inch repeated for $10^7$ cycles. With a static

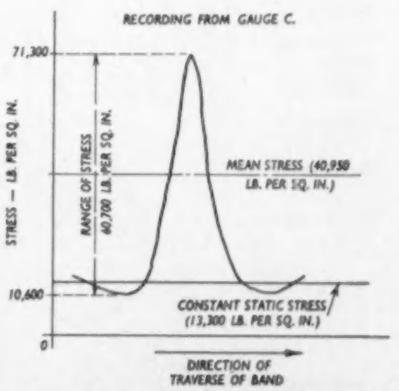
RECORDING FROM GAUGE C.
71,300
STRESS — LB. PER SQ. IN.
RANGE OF STRESS 60,700 LB. PER SQ. IN.
MEAN STRESS (40,950 LB. PER SQ. IN.)
10,600
CONSTANT STATIC STRESS (13,300 LB. PER SQ. IN.)
0
DIRECTION OF TRAVERSE OF BAND

Fig. 18—Diagram illustrating variation of maximum longitudinal tensile stress—band passing over type A fixed wing troughing roller

tensile stress applied there is a reduction in the maximum range of fatigue stress. This range approaches zero as the static tension approaches the ultimate tensile strength of the material.

Fig. 18 is a composite diagrammatic presentation of the stress variation over a fixed wing troughing assembly. The diagram includes the calculated tensile stress based upon pretensioning and coal-loading figures, and the maximum bending stress variation obtained from recordings of gauge *C*. The range of stress, which is defined as the algebraic difference between maximum and minimum stress, is shown to be 60,700 lb per square inch and the mean stress reached 40,950 lb per square inch. Substitution of the latter figures, together with the previously reported values of fatigue tensile strength, (i) in the modified Goodman Law, and (ii) in Gerber's Parabolic Law, produced calculated ranges of stress of 76,000 lb per square inch and 94,300 lb per square inch respectively, i.e. an average of 80,000 lb per square inch. For normal usage a margin of safety of 25 per cent should be allowed between the maximum permissible stress range and the fatigue strength of the material. This reduces the maximum permissible range of stress to a figure of 60,000 lb per square inch, which is less than the value detailed in Fig. 18.

Gauge *C* was positioned on the band facing a curved corner edge of the butt strap. It is reasonable to assume that for similar loading conditions, using the fixed wing roller, the longitudinal bending stresses close to the edges of the butt strap would be of a higher order. Neglecting the cracks developed at or near two kinks in the band, over 90 per cent of the fractures occurred at the centre or near the leading and trailing edges of the butt straps.

## Conclusions

In consequence of the above findings it was concluded that the cracks in the edges of the band were primarily caused by the troughing action of the fixed wing rollers. These units were subsequently replaced with articulated type of rollers, and continued routine checks with the crack-detection instrument have indicated virtually a complete cessation of crack development. It is the opinion of the authors that the relatively inflexible steel band requires perfect alignment at the joints, perfectly straight and stable roadway conditions, perfectly installed conveyor idlers and structure and generally ideal maintenance.

## Acknowledgment

The work described in this paper was carried out as part of the Research Programme of the Scientific Department of the National Coal Board, and is published by permission of the Director General of Research.

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Weir, Adam L., "Steel-Band Conveying in a Steep Drift," *Colliery Engineering*, June, 1957.
Weir, Adam L., "Steel-Band Conveying in a Steep Drift," *Colliery Engineering*, July, 1957.

# Dounreay Fast Reactor

(*Concluded from page* 1050, *December* 23)

## No. IV—HEAT TRANSFER CIRCUITS AND REACTOR CONTROL

*A symposium on the Dounreay Fast Reactor, arranged by the Institution of Mechanical Engineers, under the aegis of the British Nuclear Energy Conference, was held in London on December 7. The second paper, by R. R. Matthews,* W. G. Hutchinson,† P. K. Richards,‡ A. S. Fenemore,§ and M. H. Ewbank,‖ dealt with the design and construction of the Dounreay Fast Reactor heat-transfer circuits, steam generating plant and reactor-control system. Extracts from this paper are reproduced below.*

### Secondary Circuits

Sodium-potassium coolant is circulated through each of the 12 secondary circuits from the primary-secondary heat-exchanger to the liquid-metal-water-steam heat-exchanger by two electromagnetic pumps installed in parallel in the cool return leg of each circuit. Two cold traps similar in design to the primary cold traps are installed in a bypass loop in parallel with the main circuit at the top of each circuit, and in series with these two traps is an expansion tank. Again, as in the primary circuits, the free surfaces are blanketed with nitrogen maintained at an operating pressure of 50 lb per square inch gauge and provision is made for depressurising each circuit individually or all circuits together at shut down. Flowmeters, level indicators and pressure transmitters, all similar to the primary instruments, are fitted to each circuit.

The circuits are constructed of 6in diameter stainless steel pipe lagged with 3in thick preformed mineral-wool insulation and all pipe work and vessels are maintained at 150 deg. Cent. during shut-down by resistance heating elements approximately 6ft long strapped to the metal surface underneath the lagging. These elements are connected alternately to two independent electrical circuits supplied from opposite sides of the auxiliary plant switchboard, so that failure of one circuit will not entail complete loss of heating to the NaK and consequent risk of plugging.

*Liquid-Metal-Water Heat-Exchangers.* — Sodium-potassium or sodium reacts violently in contact with water and as little information was available during the intitial design stage of the magnitude of this reaction, it was decided to contruct heat-exchangers such that a leak of NaK or water, if it occurred, could be detected before there was any possibility of the two liquids coming into contact. It was important to ensure that no accident in a heat-exchanger could cause damage to equipment associated with other heat-transfer units, and also that pressure waves could not be set up in a secondary circuit which might be transmitted to a primary circuit and cause damage.

It was therefore decided to have the NaK and water or steam flowing in separate tubes connected by a good heat-conducting material which also provided a leak path to atmosphere. The first method attempted was to cast an aluminium block round the stainless-steel sodium-potassium and water tubes, aluminium being chosen because it has good thermal conductivity and approximately the same coefficient of expansion as stainless steel. Several elements were made and tested in a NaK rig, but this method had the disadvantage that a good bond of stainless steel to aluminium could not always be guaranteed and consequently a consistent overall heat transfer coefficient could not be obtained.

The method of construction finally adopted for elements of the heat-exchanger was to braze the stainless steel tubes to 8ft long packs of ¼in thick copper laminations as shown in Fig. 15. This was achieved by assembling a pack of laminations in a holder, coating the tubes with flux and spirally winding them with strip brazing foil.

The tubes were expanded so as to form a tight fit in the copper and the complete element was then inserted into a firing tube and purged with completely burnt town gas. It was then heated to 950 deg. Cent. and held at this temperature for 40 minutes. After cooling, the tubes at each end of the element were bent as required for assembly and welding (Fig. 15).

A complete heat-exchanger of 6MW capacity consists of a group of the above elements with twenty elements per row and thirteen rows high. The NaK flows in parallel paths from bottom to top of the heat-exchanger while on the steam-water side connections are made to the economiser, evaporator and superheater sections of the boiler plant, also shown in Fig. 15. This type of heat-exchanger is expensive and it was decided that initially only half the required heat-exchanger capacity would be installed, and that this could be extended in the future using the same design or one that had been further developed and was less costly.

The vertical columns of elements are suspended freely at their centre points by pin-jointed links connected to tie rods which are in turn supported by an overhead horizontal beam. This allows differential thermal expansion to take place without high stresses occurring. At present two heat-exchangers, each of nominal 3MW capacity, that is, with ten rows of elements instead of twenty, are housed in a common, cubicle giving six cubicles in all. The sides, top and bottom of these cubicles are made from 3in thick steel boxes packed with mineral-wool insulation and with penetrations for all the NaK, steam, and water pipes and the heat-exchanger support rods. Each cubicle is fitted with electric heaters so as to maintain a temperature of 150 deg. Cent. when the reactor is shut down. The bottom of the cubicle is fitted with deflector plates which guide any leakage of NaK into a tray. This tray is fitted with a leak detection element consisting basically of two conductors which would be short circuited by leaking NaK giving a signal. The cubicle is also fitted with fire fighting equipment below the heat-exchangers complete with external connections suitable for portable fire fighting units.

### Heat Rejection Plant

The long-term testing programme envisaged for the reactor involved a gradual build-up to full power and operating temperature. It was necessary therefore for the heat-rejection system to be capable of removing the heat generated over a wide range of temperatures and powers independent of the electrical generation. When generating steam at 185 lb per square inch gauge the primary NaK inlet temperature to the reactor vessel will not be less than 190 deg. Cent., but

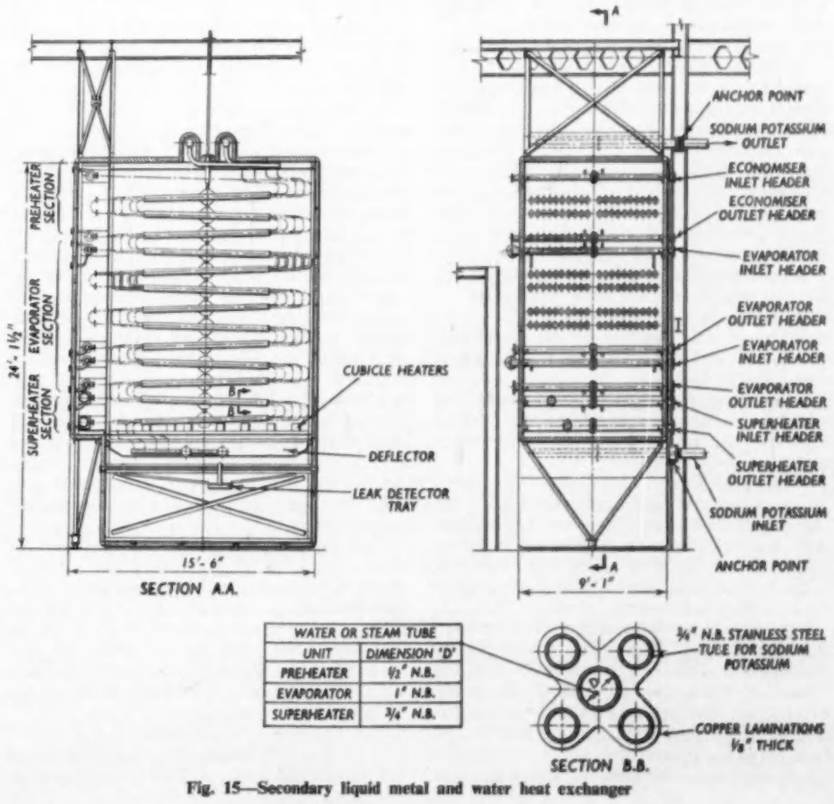


**Fig. 15—Secondary liquid metal and water heat exchanger**

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§ Head of Electrical Machines Laboratory, Nelson Research Laboratories, The English Electric Company, Ltd., Stafford.
‖ Director, Ewbank and Partners, Ltd., London.

lower temperatures will be required during intial operation. It was therefore decided to design the plant for two conditions:

(1) Pressurised water cooling during initial operation allowing the NaK inlet temperature to the reactor vessel to vary between 100 deg. and 200 deg. Cent.

(2) Steam generation at 185 lb per square inch gauge and 280 deg. Cent.

A Lamont forced-circulation boiler system was chosen as being the most suitable for this purpose. This was arranged conventionally with an economiser, evaporator, and superheater when operating as a steam generator, but with only a section of the evaporator in use when rejecting heat by pressurised hot water.

The dump condensers were also designed to fulfil the dual function of pressurised water coolers initially, with simple conversion to steam condensers during the later stage. In order to achieve this a special partially baffled heat exchanger was designed with vertical tubes, water inlet and outlet connections on the side and a steam connection on top.

The system of control for the two operating conditions is as follows:

*Water cooling.*—Water is drawn from the steam drum by the circulating pump, passed through the dump condenser and returned to the drum through the secondary heat-exchanger. The control of the temperature level in the heat-exchanger is carried out by a water bypass system. One flow control valve is in series with the dump condenser and controls the flow of water through the dump condenser under the influence of the temperature of the water returning to the heat-exchanger. This controller can be set to give any predetermined temperature. The bypass flow control valve maintains constant flow round the heat-exchanger circuit.

*Steam generation.*—During steam generation, all sections of each secondary heat-exchanger are in commission. From the superheater steam passes through the dump spill valve to the dump condenser. This spill valve maintains a constant steam pressure on its upstream side and the subsequent variable pressure in the dump condenser is used to vary the level of the condensate and thus it acts as a variable surface condenser. A constant head of water is maintained on the condenser by the condensate return to the surge tank. In order to prevent the possibility of blowing steam through to the feed system a manually reset automatic shut-off valve is fitted at the condensate outlet from the dump condenser.

Steam from the twelve heat-exchangers can also be passed to a common header for the supply to the turbo-alternator. This is a standard 15MW machine designed for steam conditions of 150 lb per square inch gauge and 270 deg. Cent.

In other respects the boiler plant is conventional using standard fittings and mountings such as valves, boiler feed regulators, and blowdown equipment.

*Water Treatment.*—Because of the novel design of the secondary heat-exchangers, and the troubles which have been experienced with chloride stress corrosion of austenitic steels, it was decided to provide full-scale water treatment in line with modern practice on high-pressure boilers.

The raw water is treated in a mixed-bed demineralisation plant and then passed through a deaerator to the reserve feed tanks. Chemical dosing is provided to the boiler drums and facilities are available to recirculate this round the system to the reserve feed and surge tanks and the condensate return from the main turbine condenser. The reserve feed and surge tanks are provided with a nitrogen blanket.

Two shunt deaerators are installed to provide deaerated make-up and for recirculation of the water stored in the reserve feed and surge tanks. When the plant is operating on water dumping very little make-up will be required and in order to avoid overheating of the deaerator recirculation water, a water cooler is fitted on each deaerator discharge.

*Commissioning the Steam Generators.*—The commissioning procedure is complicated by the necessity to avoid freezing of the NaK by cold water. All sections of the plant except the secondary heat exchanger are first filled with treated water which is circulated round the evaporator section pipe work via the evaporator bypass by means of the forced circulation pump. Factory steam is then injected into the boiler drum and when the water has reached the maximum temperature it is admitted a little at a time into the evaporator section until it is flooded. This has to be carried out carefully to avoid excessive flashing of the water to steam if the temperature of the water is less than the liquid metal temperature. Following this the plant may be operated on water cooling or steam passed to the dump condenser via the superheater. At this stage feed water is supplied direct to the boiler drum via the economiser bypass. Finally the economiser may be commissioned in a similar manner to the evaporator.

## Reactor Controls

The reactor is controlled from a reactor control room outside the sphere and during normal operation there is no necessity for personnel to be stationed inside the sphere. All reactor controls and measurements essential for correct operation are installed on a central desk, while measurements which give general information and only require periodic checking are displayed on panels surrounding the room. These panels also contain the alarm and reactor trip circuits, and one panel is allocated to the oscillator controls and instruments, which are used for analysing reactor stability.

*Neutron Detectors.*—Thermal neutron detectors operating conventional electronic equipment are employed to provide information on power level, drift and power doubling time. The physics information which was used to establish the range and type of equipment to be employed was obtained from measurements made in an experimental column on the ZEUS reactor. Measurements of neutron flux are required from shut-down level up to and beyond full-power operation and to achieve this range, three groups of instruments are employed, operating between 50mW and 100W, 2W and 2MW, and 1MW and 100MW. The range of measurement required has been reduced to a practical minimum by the use of a 10 curie radium-beryllium neutron source. To reduce the risk of this source being damaged at high power levels, it is designed so that it can be withdrawn from the reactor, withdrawal and insertion being controlled from the reactor control room.

The neutron detectors are installed in twelve holes in an equatorial belt of pure graphite contained within the neutron shield surrounding the reactor vessel. The temperature of the neutron shield will be above 200 deg. Cent. and the detectors are gas cooled as they will not operate satisfactorily over long periods at temperatures above 90 deg. Cent.

The detectors provided are:

(1) Three $U^{235}$ coated fission chambers for low-power channels. (2) Two ion chambers for intermediate-power channels. (3) Eight ion chambers for high-power channels. (4) One ion chamber for use with the oscillator.

All detectors except for those in (3) are made retractable and in two cases two detectors are fitted in the same hole.

The cabling between the neutron detectors and the associated electronic equipment is of the high impedance type, while all cabling passing through the sphere shell had to be of "Pyrotenax" to obtain satisfactory gas-tight seals.

*Control Desk.*—The reactor operating conditions are controlled by the following:

(1) Power output by moving control rods.

(2) Temperature rise through the core by altering primary coolant flow rate.

(3) Coolant inlet temperature by altering

(*a*) secondary coolant flow rate when generating steam;

(*b*) secondary coolant flow rate and water bypass flow rate round the dump condenser when rejecting heat by pressurised water.

No variation in sea-water flow rate is required when altering temperature conditions in the reactor and it is planned that at all times a sufficient number of sea-water pumps should be running to remove the reactor heat even when a failure of one of these pumps occurs. When generating steam the boiler units are slaves to the reactor, and by reason of the variable surface condensers and automatic feed regulators to the boiler drums their response to variation in reactor output is automatic.

The reactor output is controlled by the movement of six or less control rods and these are manually operated by switches on the desk giving a normal "in" speed, a normal "out" speed and a fast "out" speed to control power overshoots. A master selector switch enables the control rods to be moved as a group or singly. During start-up the same switch can select group movement of the safety rods, boron shut-off rods or shut-off rods, the energising relays being interlocked with the rod limit switches so that they can only be raised in that order. This interlock can be bypassed during shut-down by means of a key system so that one single rod, and only one, can be raised at a time for test purposes. The normal speed switches can, at the discretion of the operator, be set by a timer to operate continuously for intervals up to five minutes, to assist during start-up periods when the complete stroke of a rod takes 140 minutes. Otherwise when controlling the reactor the switches only operate by continuous pressure from the operator. The positions of the control rods are shown by six dial-type indicators with a high incremental sensitivity, while the positions of the remaining rods are displayed on the central panel.

The reactor power level is indicated by a power drift recorder in the centre of the desk supplemented by a logarithmic high-power and low-power neutron-flux recorder and a linear high-power recorder. In addition, a linear flux indicator (0–100MW) provides measurement of neutron flux should all power supplies fail and is connected directly to one of the high-power ion chambers. The ion chambers are supplied from batteries and indication will be given until these batteries are exhausted.

Reactor doubling time is shown on an indicator provided with a selector switch for the high-, intermediate-, and low-power channels.

The primary and secondary pump flow rates can be altered by "increase" or "decrease" switches which vary the voltage from the induction regulators in the Diesel

TABLE—*Heat Removal System Data, 60MW(H) Core Output*

| | |
|---|---|
| **Coolant :** | |
| **Primary and secondary circuits :** | |
| 70/30 per cent by weight sodium-potassium alloy | Coolant |
| Melting point | 40° C |
| Boiling point | 825° C at atmospheric pressure |
| Density | 53·3 lb/ft³ at 300° C |
| Thermal conductivity | 16·0 c.h.u./ft²/h °C ft at 300° C |
| Specific heat | 0·272 c.h.u./lb °C at 300° C |
| **Thermal syphon circuits :** | |
| 22/78 per cent by weight sodium-potassium eutectic alloy | 70/30 per cent |
| Melting point | −11° C |
| Boiling point | 784° C at atmospheric pressure |
| Density | 50·0 lb/ft³ at 300° C |
| Thermal conductivity | 15·0 c.h.u./ft²/h °C ft at 300° C |
| Specific heat | 0·212 c.h.u./lb °C at 300° C |
| **Primary circuits :** | |
| Number of core circuits | Twenty |
| Number of breeder circuits | Four |
| Heat-transfer duty of core or breeder circuit | 3MW(H) |
| Number of pumps per circuit | One |
| Flow rate per circuit | 40·5 lb/sec |
| Pressure drop external to reactor vessel | 13 lb/in² |
| Total volume of NaK (referred to 300° C) | 21600ft³ |
| Total weight of NaK | 51·3 tons |
| **Primary-secondary heat exchanger :** | |
| Inlet temperature | 350° C |
| Outlet temperature | 200° C |
| Heat-transfer service | 378ft² |
| Mean temperature difference | 20° C |
| **Electromagnetic pumps :** | |
| Flat linear induction type : | |
| Flow rate | 40·5 lb/s |
| Pressure drop (core circuit) | 24 lb/in² |
| Line voltage | 410V |
| Kilowatts | 14·7 |
| kVA (after power factor correction) | 16·5 |
| Pump efficiency at 410V and 40·5 lb/s | 24 per cent |
| Minimum pressure at pump inlet | 12 lb/in² gauge |
| Maximum allowable winding temperature | 240° C |
| **Cold traps :** | |
| Number of traps | Fifteen |
| Flow rate through trap basket | 0·26 lb/s |
| Volume of basket | 2ft³ |
| Packing | Stainless steel rings ¼in diameter × ¼in long × 20 S.W.G. |
| NaK residence time | Five minutes |
| Trap inlet temperature | 200° C |
| Trap basket temperature | 100° C minimum |
| Trap outlet temperature | 195° C |
| **Hot traps :** | |
| Number of traps | Five |
| Flow rate through trap | 2·1 lb/s |
| Oxide absorption material | Zirconium foil 0·005in thick |
| Surface area in contact with NaK per trap | 400ft² |
| Trap inlet temperature | 200° C |
| Temperature of NaK flowing over zirconium | 600° C |
| Trap outlet temperature | 220° C |
| Electrical heating input | 35kW |
| **Blanket gas system :** | |
| Gas | Nitrogen |
| Operating pressure | 50 lb/in² gauge |
| Shut-down pressure | 0·5 lb/in² gauge |
| Volume of system including buffer tanks | 2370ft³ |
| **Secondary circuits :** | |
| Number of circuits | Twelve |
| Heat-transfer duty per circuit (final) | 6MW(H) |
| Number of pumps per circuit | Two |
| Flow rate per pump | 38·3 lb/s |
| Pressure drop | 26 lb/in² gauge |
| Number of cold traps per circuit | Two |
| **Primary-secondary heat-exchanger :** | |
| Inlet temperature | 170° C |
| Outlet temperature | 330° C |
| **Liquid-metal-water heat-exchangers (as originally designed for 60MW(H) output steam generation) :** | |
| Heat-transfer duty | 6MW(H) |
| NaK flow rate | 76·6 lb/s |
| Steam generation rate | 16,800 lb/hour |
| **Pre-heater section :** | |
| Water inlet temperature | 40° C |
| Water outlet temperature | 173·5° C |
| Heat-transfer surface area | 90ft² |
| **Evaporator section :** | |
| Water-steam pressure | 200 lb/in² gauge |
| Water-steam temperature | 195° C |
| Heat-transfer surface area | 400ft² |
| **Superheater section :** | |
| Steam inlet temperature | 195° C |
| Steam outlet temperature | 280° C |
| Pressure at outlet | 185 lb/in² gauge |
| Heat-transfer surface area | 78ft² |
| **Thermal syphon circuits :** | |
| Number of circuits | Four |
| Heat-transfer duty per circuit during thermal syphon conditions | 0·45MW(H) |
| **Steam plant :** | |
| **Dump condenser :** | |
| Number of condensers | Twelve |
| Type : vertical shell and tube | |
| Duty : to condense generated steam or to cool pressurised water | |
| Total surface area | 1980ft² |
| Maximum sea-water flow rate | 367 lb/s |
| **Feed pump :** | |
| Number of pumps | Twelve |
| Type : Six-stage centrifugal | |
| Duty | 7·1 lb/s |
| Suction pressure | 0·5 lb/in² gauge |
| Discharge pressure | 300 lb/in² gauge |
| **Circulating pump :** | |
| Number of pumps | Twelve |
| Type : Single-stage, centrifugal, submersible motor | |
| Duty | 44·1 lb/s |
| Head | 59·5ft |

generator house. A selector switch enables pumps to be adjusted in pairs or in groups. Normally the twenty-four primary pumps and the twenty-four secondary pumps will be altered together and individual pairs will be altered for trimming only, although variation in overall flow rates through the core and breeder may be required separately. Indicators showing the summated coolant flow through the primary core and primary breeder circuits, and through the secondary core and secondary breeder circuits, are provided, while the coolant outlet temperature from the core immediately below the centre channel is shown on a recorder.

When rejecting heat by pressurised water a further set of controls are required, provided on a temporary extension to the desk. This extension includes a pre-set temperature control for the water returned from the dump condenser in each of the twelve circuits and indication of these temperatures.

*Panels.*—The main feature of the panels surrounding the desk is a mimic diagram used for periodic checking which will provide information on the state of individual circuits, and which can be referred to if it is suspected that one or more of the circuits is deviating from the required operating condition. It is impossible to indicate simultaneously the measurements from all circuits so the mimic diagram was designed to show one heat-transfer unit, comprising the two primary circuits, one secondary circuit, and one steam generating plant. Twelve-point indicators show the coolant flow, inlet and outlet temperatures of the reactor vessel in each primary circuit, the coolant flow, blanket gas pressure, inlet and outlet temperatures of the primary heat-exchanger in the secondary circuit, and also the steam pressure and superheater outlet temperature. By operation of the appropriate selector switch on each indicator it is possible to obtain simultaneously these measurements in any one heat transfer unit.

Additional indicators show the blanket gas pressure and coolant level in the primary circuits, and coolant flow, and temperatures in the thermal syphon circuits while at the steam plant end the sea water flow rates and turbo-alternator output are shown. The centre panel also indicates the positions of the safety shut-off and boron shut-off rods and contains additional recorders for neutron flux power and reactor doubling time. A recorder is also provided to show increased activity in the primary circuits which is characteristic of a fuel can failure, signals being transmitted from four coolant monitor circuits while another recorder shows any gamma activity in the sphere atmosphere.

Panels inside the sphere show measurements which are non-essential for reactor operation, such as concrete or graphite temperatures, performance of the various cooling systems, and performance of cold and hot traps, but which require to be checked periodically or recorded for reference. Where necessary, alarms are provided from these measurements to the reactor control room to warn the operator of faults which require corrective action, but in general these faults would not immediately affect reactor operation.

*Trip Circuits.*—The reactor may be tripped on detection of an abnormal condition in any one or any combination of the following measurement systems:

(1) Core centre channel coolant temperature.

(2) Coolant flow in core and breeder.

(3) Primary blanket gas pressure.

(4) Neutron flux level on low-power operation.

(5) Reactor doubling time on low-power operation.

(6) Reactor doubling time on intermediate-power operation.

(7) Neutron flux level on high-power operation.

(8) Reactor doubling time on high-power operation.

In addition the reactor may be tripped by operation of the emergency shut-down button on the control desk.

Except for items (2) and (6) three independent channels are provided for measurement and the two out of three coincidence system is used, that is, a trip only occurs if at least two out of three channels detect the abnormal conditions, so guarding against a spurious trip caused by fault of any one channel. The total coolant flow is obtained by summating the flow in each circuit ; to provide more than one measurement on each circuit would be prohibitive, so in this case only one channel is available. The limitation of space in the instrument tube holes also allowed only two channels for intermediate power reactor doubling time. Bypass facilities are included for all trip circuits except those for reactor doubling time and flux level on high-power operation. During normal-power operation when starting up or shutting down it is essential that for some of the time systems (2)–(6) are bypassed. An indication of the trip bypass switches in use is presented at the reactor control desk.

*Alarms.*—Altogether there are nearly 250 alarm circuits displayed on one panel in the reactor control room. The system has been designed to give indications of faulty operation at key points throughout the plant in a form convenient to the operator. The main indications are given in the reactor control room but some alarms are repeated in the sphere and heat-exchanger house.

Thus the system is split into four main divisions :

(1) Alarms indicating a reactor trip.

(2) General alarms denoting faults in particular circuits or items of plant.

(3) Alarms displayed in the sphere.

(4) Alarms displayed in the heat-exchanger house.

A separate alarm is provided for each reactor trip circuit parameter and the general alarms are classified into eighteen groups as follows :

(1) High temperature, coolant circuits ; (2) Low temperature, coolant circuits ; (3) Primary coolant leak ; (4) Coolant contaminated ; (5) Coolant level low ; (6) Coolant flow failure ; (7) Gas blanket pressure low ; (8) Flow failure, boiler circuits ; (9) Sea-water flow failure ; (10) Safety circuit alarms ; (11) Power supply failure ; (12) Vault cooling failure ; (13) Safety rods not at top of travel ; (14) Shut-off rods not at top of travel ; (15) Neutron-flux equipment in operation ; (16) Compressed air failure ; (17) Fire ; (18) Spare.

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LOW-POWER TELEVISION STATION AT HASTINGS.—As part of its plan to extend television service and to improve reception in areas where this is not at present satisfactory, the B.B.C. has begun experimental transmissions from a low-power television transmitting station at Hastings. This is an experiment in the use of a very low-power translator of a new pattern which has been developed by the B.B.C. It is hoped that such translators will be found suitable for improving reception in a number of other towns at a later stage. The station picks up the Crystal Palace transmissions and re-radiates them on Channel 4 (vision 61·75 Mc/s, sound 58·25 Mc/s). Transmissions are horizontally polarised. Although its range cannot accurately be predicted the new station will provide many thousands of people in Hastings and St. Leonards with an improved standard of reception. Aerials with the elements horizontal are necessary for receiving the new transmissions.

# LETTERS AND LITERATURE

## Letters to the Editor

### STIFFNESS OF A CRANE JIB

SIR,—The interesting article "Stiffness of a Crane Jib," in the "Technical Contributors Section" of your issue of July 29, 1960, pages 181 to 187, is, I am sure, likely to appeal not merely to crane designers but to all those of your readers who are in one way or another concerned with the theory of buckling, because it deals with a stability problem outside the scope of the basic buckling cases commonly treated with the Euler formula, the buckling structure being subjected to an end restraint of any value between zero and infinity. The authors give in Fig. 4 of the article a theoretical curve for the variation of effective length ratio $l/L$ with a certain ratio of dimensions, $C/A$; this ratio $C/A$ can be shown to be closely related to the end restraint.

The problem considered is that of the jib of a derricking crane, buckling in a plane normal to the plane of luffing, due regard being given to the fact that the jib head is, in case of lateral deflection $\Delta$, subjected to a restraining force $F$, owing to the action of the hoist and derricking ropes. May I be allowed to point out that an analytical expression for the effective length of the jib for this particular case of buckling can be easily derived in a few steps from the general buckling equation recently discussed[1] for a strut of length $L$ and flexural rigidity $EI$ with arbitrary degrees of end fixity, $\mu$ and $\nu$ respectively, and an end restraint $c$ :

$$\phi-(\mu+\nu)\,p-\mu\nu-\frac{c}{\phi}[\phi-(\mu+\nu)(p-1)-\mu\nu(1-q)] =0,$$

where

$$p=\sqrt{\phi}\cot\sqrt{\phi},\quad q=\tan\left(\frac{\sqrt{\phi}}{2}\right)\Big/\left(\frac{\sqrt{\phi}}{2}\right)$$

$$c=FL^3/\Delta EI.$$

From the "specific collapsing load" $\phi$ determined by this equation either the buckling load $P_{crit}$ or the equivalent buckling length $l$ is obtained according to the relationship

$$\phi=P_{crit}\,L^2/EI=(\pi L/l)^2.$$

For the jib under consideration acting as a whole as a strut with base clamped ($\mu=\infty$) and top free to rotate ($\nu=0$) the general equation reduces to

$$-\frac{c}{\phi}\left(1-\frac{\tan\sqrt{\phi}}{\sqrt{\phi}}\right)-1=0$$

What remains to be done is to find $c$ in terms of crane geometry and rope loads. As to the ratio $C/A$, shown by the authors to be the determining independent variable, it follows from their equations (2) and (9) together with the expression given for $A$ that, assuming the jib being loaded by the critical load,

$$F/\Delta=CP_{crit}/AL,$$

consequently

$$c/\phi=C/A$$

and hence finally, substituting $l/L$ :

$$\frac{C}{A}=\frac{1}{1-\tan\left(\frac{\pi L}{l}\right)\Big/\left(\frac{\pi L}{l}\right)}$$

This expression is essentially the same as the authors formula (13) and quite convenient to work with directly—no need of tabulated instability functions.

Introducing $D=A-C$ gives, with the horizontal distances $C$ from jib head to jib foot and $D$ from jib foot to the point of intersection of the line joining the two fixed pulleys and the line of the resultant of the rope forces, $D$ to be taken negative if this point lies in front of the jib pivot,—

$$-\tan\sqrt{\phi}/\sqrt{\phi}=D/C,$$

a concise formula for determining the specific collapsing load of the jib of a luffing crane buckling in a plane normal to that of luffing.

DR.-ING. M. J. GERCKE

Dusseldorf,
Western Germany,
November 23, 1960.

[1] Gercke, M. J., "Collapsing Load of a Strut with Elastically-Fixed Ends," *Engineering*, Vol. 176 (1953), pages 67–70; "Über die allgemeine Form der Knickbedingung des geraden Stabes," *Konstruktion*, Bd. 4 (1952), pages 46–54; "Die Verallgemeinerung der Eulerschen Knickformel," *Der Bauingenieur*, Bd. 27 (1952), pages 433–36.

### SCREWY SCREW THREADS

SIR,—In a leading article in your issue of July 15 you gave it as your opinion that the British Standard Fine thread is decisively preferable in certain respects to the nearest Unified thread. I wrote you two letters agreeing with your opinion, which you published on July 29 and September 23, but there has been no other comment from your readers. In spite of this lack of interest in the subject, you may perhaps care to publish the following further reflection on screw thread strength.

Everyone knows that a bolt with too coarse a screw thread is weak because of its restricted core area. Equally, everyone—or nearly everyone—thinks that there is truth in the converse; that using a fine pitch increases bolt strength and only manufacturing considerations are the limit. This apparently is not so. Considering the load concentration along the mating length of a bolt and nut that results, as shown by Sopwith[1], from bolt stretch and other strains, one arrives at a formula for the peak bending stress in a thread root which is substantially

$$\text{Coefficient}\times\sqrt{\frac{\text{Diameter}}{\text{Pitch}}}\times\text{Tensile stress in bolt core.}$$

The outstanding conclusion from this formula is that stresses go up as the thread gets finer. With a sufficiently small pitch, the bending stress at the worst point will reach the material's yield or proof stress at an insignificant load on the bolt. This may not be quite the same thing as saying that an infinitely fine-pitched thread is infinitely weak but it is very near to it.

It seems theoretically, therefore, that there may be danger in moving towards fine pitches, as in the larger sizes of Unified Fine. Indeed, the whole implication of the article[2] you published on May 2, 1958, is that this danger is real and practical.

A. C. HUTCHINSON

Bedford,
December 14.

REFERENCES

[1] "The Distribution of Load in Screw Threads," by D. G. Sopwith, *Proc. I.Mech.E.*, 1948, Vol. 159.
[2] *Tightening and Tensile Tests on Joints*, by J. E. Field.

### NEW WATER POLICY FORESHADOWED ?

SIR,—With reference to your editorial under the above title dated December 16, one might express the hope that the growing interest in water conservation in this country will at last necessitate modern organisation in gauging river flows, with proper publication of the results. For any economic design connected with water conservation, records of flow for at least fifteen consecutive years are necessary.

In this country, with very few exceptions, such long-term records are sadly lacking. True, the *Surface Water Year Book* improves the position each year, but in comparison with any Continental country British records are quite inadequate. In Continental countries practically every river has records for the past thirty years at least, and many for a much longer time. Also, Commonwealth countries like Australia, New Zealand and South Africa have records, for many rivers, much longer than in this country.

The expense of proper gauging organisation is negligible in comparison with the cost of possible mistakes. It should also be stressed that the British rainfall records are excellent, and there is really no reason why flow records should lag behind. What is required is a decision to organise gauging properly, and to spend a little money on it.

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Ph.D., D.I.C., M.I.C.E.

Westminster,
December 19, 1960.

## Book Reviews

**Jane's All the World's Aircraft**, 1960–61. Edited by JOHN W. R. TAYLOR, F.R.Hist.S., A.R.Ae.S. Sampson Low, Marston and Co., Ltd., Potter Row, Great Missenden, Bucks. Price 105s.

IN the foreword to this year's *All the World's Aircraft* it is pointed out that, in conflict with the belief prevailing in this country that aviation has passed the stage of expansion in which it was worthy of investments of man-power and resources, more new aeroplanes than ever have appeared, and that the variety is so great as to show that in all probability the most rewarding decade in the progress of aviation is approaching. Since the British engineer is now condemned to learn at third hand of these developments, the importance of "Jane's" is enhanced, and it is reassuring to note the care with which the compiler is charting a course for years to

come. The definition of an aircraft is laid down as a vehicle that travels through the air, thus cleverly avoiding any questions as to why unmanned aerostats are excluded, and forestalling the protests of, perhaps, Folland when ground effect machines with wheels or screws appear. Powered lift machines, not to mention rotor craft, are in fact becoming so numerous that the index heading "Aircraft" (which is used to exclude aerostats) seems more appropriate than the section title "Aeroplanes." It must be observed, however, that the table of First Flights contains some entries that hardly denote significant advances into the challenging future, such as the de Havilland "Comet" 4C, the Bristol/Canadair "Sabre" ("Orpheus" engine), the Flight Refuelling/Gloster "Meteor" U. Mk.16, and the Westland "Westminster" (covered fuselage).

Once one plunges into the pages there is as always an abundance of interest. A swift impression is that a strong trend exists towards fitness for function, so that aerodynamic considerations are not allowed to make aircraft for different purposes look alike; on the other hand, there seem to be more examples of mechanically complicated pusher airscrew installations being undertaken for aerodynamic reasons—one suspects that interest in soaring and man-powered flight may have spread enlightenment in this particular. Another development more distinct and more significant is the intrusion of the turbine on the embattled stronghold of the piston engine, the light aeroplane. Apart from variants of military trainers, there are "Astazou" installations in a Nord 1110 and a "Turbo-Travel Air," the Procaer "Cobra" 400 with the remarkable speed, for a light aeroplane, of 380 m.p.h., and the S.I.P.A. "Présence" with a development programme a mere six months behind that of the Short "Skyvan"—it is not yet clear whether it may be the licensor and not the licensee of Continental Motors Corporation that has prospects in this field.

This year's compilation lives up to the claim *All* perhaps more fully than of late, and the result is the inclusion of some quite remarkable machines, such as the Hoffman "Sweet Patootie" X-1 which "represents an attempt to combine the Spitfire's semi-elliptical (*sic*) wing planform with the type of elongated fuselage used in the pre-war designs of Mr. F. G. Miles" (according to its constructor) while for elegance in nomenclature the palm goes to Akaflieb Darmstadt, who modified their sailplane "Aphrodite" and named it "B'phrodite." Worthy of more serious commendation is the Trans-Florida "Executive 'Mustang' 2000," a two-seat version of an F-51D with the remarkable maximum speed of 505 m.p.h. and the severely functional Bennet "Airtruck" which has two separate tails or booms to afford easy loading of fertilisers and insecticides. Of particular value are illustrations of such little-known machines as the "Bounder," which one feels must make the bombers of S.A.C. seem modest in their runway requirements, the Curtiss-Wright X-100 that exploits the "radial" force developed in the plane of rotation of a propeller, and the saucer-shaped Avro "Avrocar."

Fresh frontiers are rapidly opening before the propulsion engineers, and this year we see references, if sometimes brief, to a S.N.E.C.M.A. ramjet for speeds between M. 1·5 and M. 4·2 having a variable-geometry convergent-divergent nozzle, the ambitious Meteor family of X-four and X-eight supercharged two-strokes with an electrically energised fuel injection system and a consumption of 0·485 lb per horse-power hour, and the Allison "Pyrodyne," a ramjet burning an unspecified pyrophoric fuel. Some of these references are tantalising in the extreme, and one may feel that it would be a gifted reader who could visualise the adiabatic operation of the Pratt and Whitney liquid hydrogen engines from the mere phrase "a regenerative cycle."

The "Airships" section is notably more eclectic than before, with a section on the Goodyear-derived German non-rigids and another for Mississippi State University, where the Aerophysics Department is investigating at full scale the application of boundary layer control, which should reduce to zero the drag of an aerostat.

This edition can claim a particularly attractive and interesting collection of photographs, such as the separation of a "Snark" warhead, a "Scimitar" making a rocket attack, a "Hustler" with a J-93 engine in a pod with an oblique shock intake, and the Heat Transfer Reactor Experiment No. 3 showing the two G-E J-47 jet engines and the reactor, which is mounted horizontally with the control rods parallel to the engines. It is, however, becoming clear that the editor must grapple with the problem of products appearing under different maker's names. The Lycoming-engined "Drover" appears under "De Havilland Aircraft Company (Pty.), Ltd." with no mention of the fact that the original aircraft had one engine and syllable the less, while the Lycoming-engined "Heron" appears under "Vest Aircraft de Mexico, S.A." and is indexed under "Super Heron." Derivatives, acknowledged or otherwise, of the Volkswagen engine blossom practically at random through the pages!

**Jane's Fighting Ships** 1960-61. Edited by R. V. B. BLACKMAN. Sampson Low, Marston & Co. Ltd., Potter Row, Great Missenden, Bucks. Price 105s.

APART from those whose jobs are directly or indirectly connected with naval affairs, there are a large and increasing number of thinking people who believe that a nation may decide on war in pursuit of policy without committing suicide by using mass destruction weapons. It is to them that "Janes' Fighting Ships" has such a strong appeal; for in each new edition there is usually a mass of fresh material. The 1960-61 issue is no exception. In addition to the amplification and revision of technical ship data it contains some 470 new illustrations comprising 443 photographs and 27 drawings. The editor attributes the need for so many amendments and additions to the different types of warships now emerging from the shipyards and to the extensive reconstruction, conversion or modification of existing warships which completely alters their appearance. A two page spread table at the end of the book showing the number of warships in each category in all the World's navies will be found interesting but should not be used as a comparison of strength because of the difference in age and armaments of the vessels concerned. The editor also raises an important point which was emphasised six months ago in a leading article in this journal—the need for a more intelligible classification of warships. In recent years it has become customary to classify ships according to their machinery or the weapons they carry which is both illogical and confusing and is made still more complicated by the markedly different sizes of vessels within each category. Despite the elimination of the battleship and other well known and clearly defined categories of ships, it seems essential to go back to first principles and apply the criterion of function or role. This is all the more important because the N.A.T.O. Navies will be closely integrated tactically and operationally in war.

But one must doubt "Jane's" definite statement that cruisers are following battleships into obsolesence. Both the United States and Russia have a large number of these powerful self-reliant and self-contained fighting units in commission. The United States is not only building a nuclear powered vessel of this type—her intention is to build an all nuclear powered Navy. She is also rearming her existing cruisers with anti-aircraft guided missiles. True, if Mr. Khruschev is to be believed, Russia is now scrapping her cruiser force. But it might be wiser to believe a German intelligence report that they have been withdrawn from service to be fitted with these missiles. As far as Britain is concerned the problem seems to depend largely on finance. With N.A.T.O. defence policy based on the need to prevent total war with thermo-nuclear weapons it is difficult to persuade Parliament that large ships are necessary to defend the sea routes. Governed by this situation the Admiralty has been wise to concentrate on ships required to counter the principal danger facing Britain on a lesser scale war—on anti-submarine vessels. Indeed this may well be the answer to "Jane's" question—in a reference to the "Devonshire" class—"What *is* a guided missile destroyer?" These 5200 ton vessels are in fact a compromise; their tonnage suggests they are small cruisers; but with only a 4·5in gun armament the Admiralty have been able to classify them as destroyers. "Jane's" does well to emphasise the spectacular advances in efficiency given to the submarine by nuclear power. But again, the editor is on debatable ground in visualising navies consisting entirely of underwater craft. Surface ships carrying supplies and troops traverse the sea routes on the surface, and these surface routes cannot be controlled by submarines which are at the mercy of any fast vessel armed with a gun, whenever they appear on the surface. Underwater craft can dispute control but cannot gain and maintain it. The reader's main interest in this new edition will no doubt centre on the data and photographs in the United States and Soviet sections. But the whole volume is fully up to the standard required for a valuable work of reference and deserves careful examination and study.

## Books Received

*Directory of Railway Officials and Year Book*, 1960-61. Tothill Press, Ltd., 33, Tothill Street, Westminster, S.W.1. Price 60s.

*International Mineral Processing Congress*, 1960. The Instituiton of Mining and Metallurgy, 44, Portland Place, London, W.1. Price 100s.

*The Bargainers: A Survey of Modern Trade Unionism*. By George Cyriax and Robert Oakeshott. Faber and Faber, 24, Russell Square, London. Price 21s.

*Welding Handbook*. Fourth edition. By A. Phillips, American Welding Society. The Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 72s.

*Der Durchlaufende Bogentrager auf Elastischen Stutzen mit und ohne Versteifungstrager*. By Walter Stampf. Springer Verlag, Berlin-Wilmersdorf, Heidelberger Platz, 3, W. Germany. Price DM.37.50.

*Chemical Analysis of Cast Iron and Foundry Materials*. By W. Westwood and A. Mayer. Revised edition by W. E. Clarke and H. Green. George Allen and Unwin, Ltd., Ruskin House, 40, Museum Street, London W.C.1. Price 63s.

# Teaching of Metallurgy to Engineers

By T. HENRY TURNER, M.I.Mech.E., M.I.Loco.E., A.R.Ae.S. F.I.M.

Professor J. G. Ball has been Head of the Metallurgy Department, at the Imperial College of Science and Technology, since 1957. Recently, on November 16 last, he read a paper to the Institution of Mechanical Engineers at 1, Birdcage Walk, Westminster, on "Teaching Metallurgy to Engineers," a matter of importance to all kinds of engineers.

He approached the subject as a metallurgist, who followed his early studies for the B.Sc. degree in the Metallurgical Department of the University of Birmingham, with practical training and experience in both the British Welding Research Association and the Atomic Energy Research Establishment.

Almost exactly a century ago his famous predecessor, Dr. John Percy, M.D., F.R.S., Head of the Royal School of Mines, when it was still in Jermyn Street, was penning the big volume of 934 pages on Metallurgy that the present writer has before him as he writes these comments on the same old double pedestal desk that Dr. Percy used in Jermyn Street. The big book is dated 1864 and is the part on Iron and Steel of the series started in 1861 and bears the following definition as its sub-heading, "The Art of Extracting Metals from Their Ores, and Adapting Them to Various Purposes of Manufacture." Later, in 1874, the corresponding sub-title to Dr. Percy's book on Refractory Materials, and Fuel, described Metallurgy as "The Art of Extracting Metals from Their Ores." Percy wrote that he regarded certain physical properties of metals, general considerations on metallurgical processes, refractory materials and fuels as introductory to the subject of metallurgy. Before the turn of the century another famous Head of the Royal School of Mines, Sir W. C. Roberts-Austen, K.C.B., F.R.S., A.R.S.M., had tried to treat the subject as a whole, giving no minute descriptions of processes, but choosing typical appliances and indicating their use in connection with groups of metals in *An Introduction to Metallurgy*, for which another A.R.S.M., F. W. Harboard, wrote the sixth edition about 1910.

Many of the textbooks used by students of metallurgy before the 1914–18 war, such as the present writer, came from this series inspired by Roberts-Austen. They were published by Charles Griffin and Co., Ltd., London, their titles commencing with *The Metallurgy of* ... Thus we had *Gold* by Sir T. Kirke-Rose, *Silver* by H. F. Collins, who also wrote the book on *Lead*, *Non-Ferrous Metals* by Wm. Gowland, *Steel* by Harboard and Hall, and *Iron* by Thomas Turner. In this series they also had *Alloys and Their Industrial Applications* by Edward F. Law, *The Sampling and Assay of the Precious Metals* by E. A. Smith, and *Antimony: Its History, Chemistry, Mineralogy, Geology, Metallurgy, Preparation, &c.* by C. Y. Wang.

Metallography began to illuminate the nature of metals before 1914 and during the following thirty years Physical Metallurgy became established as a new scientific discipline; correlating the structures observed in metals under the microscope, with phase diagrams of equilibria in metallic systems. For most of the classical metallurgists it was unfortunate that many features of metallic behaviour came to be described in the language of mathematics, understandable to pure physicists but barely comprehensible to many others, including the so-called practical experts.

## How Many Courses are Needed?

The subject of metallurgy has expanded in many directions since 1945 and is almost unrecognisable from the metallurgy taught a generation ago. This has raised many difficult problems in the university and colleges of technology departments where the existing syllabuses have had to be stretched and trimmed. It is timely, therefore, to ask, as Professor Ball does in his paper, whether substantial changes are now needed in the teaching of metallurgy to engineers. Is the established treatment of metallurgy for engineers adequate for the purpose? What cognisance should be taken of recent developments in the science of metals?

To answer such questions one must not only consider the state of knowledge before 1939 and the changes since 1945 in metallurgy, but one must also ponder the types of engineer for which the course or courses should be devised; contrasting, for example, the quite diverse needs of mining engineers and chemical engineers. As the subject is wider and the students much more numerous it will perhaps now be possible to design more courses in metallurgy to fit the specialised needs of civil, mechanical, electrical, chemical, mining, and aeronautical groups of engineering students and the particular background of the class.

## Types of Syllabuses

The bare bones of three types of syllabus, which Professor Ball considered in his paper, may be set side by side for comparison, thus:

*Syllabus* (1)—"*Contemporary Adaptation of Classical Metallurgy*."—(*a*) Influence of manufacturing method on the properties. (*b*) Relationship between constitution and properties. (*c*) Methods of joining. (*d*) Effect of environment on metal behaviour.

*Syllabus* (2)—"*Metallic Behaviour*; *Strength of Metals*."—(*a*) Single crystals of pure metals. (*b*) Polycrystalline pure metals. (*c*) Alloying for strength. Selected aspects of the strength problem. (*d*) Manufacturing defects in metals.

*Syllabus* (3)—"*Pure Science Approach to Metallurgy*."—(*a*) Introductory theory. (*b*) Metals and alloys. (*c*) Non-metallic solids.

These may therefore be regarded as what the metallurgist would like to teach. Another syllabus may, however, be suggested on the basis of what the engineer should know that the metallurgist can teach. In brief this would cover:

(*a*) Availability of metals and alloys. (*b*) Sources of information on metals and alloys available to engineers. (*c*) Metallography of metals and metallic defects. (*d*) Environment; corrosion prevention; boiler water treatment; cathodic protection; temperature effects.

Such a syllabus would recognise that the course is not intended to make engineers into metallurgists but to help them use the available metals to the best advantage; to avoid waste and accidental breakdown.

## The Teacher

The following quotations from Professor Ball's paper point to the problem of finding the most suitable teachers of metallurgy to engineers.

"... It is still possible to find attitudes which treat both the teaching and learning of properties of materials as matters to be lightly dealt with." "... the traditional rowdiness of a class of engineers, particularly if it is large, faced by a lecturer in metallurgy (although this is not the only subject to stir the emotions)" "... there might be a tendency to put the weaker or least experienced members of staff on to the course for engineers and the difficulties might be further aggravated if the older metallurgists have maintained a resistance to accepting the trends away from empiricism."

One solution to this problem of finding the most suitable teacher has been to take on the engineering staff a metallurgist with an engineering bent. Such a post may prove a blind alley for the teacher, who, working in isolation from other metallurgists, lacks the day to day stimulus enjoyed by other teachers of metallurgy. Alternatively a bright younger member of the engineering staff with the appropriate inclination might attend at a university metallurgy department session, going to lectures, learning laboratory techniques and mixing with staff and research groups. On his return to the engineering department he should teach a reasonable course, if on the lines of the second of the syllabuses tabulated above.

Professor Ball concluded his helpful survey of the problem by making three recommendations as follows:

(1) Wherever possible, separate syllabuses should be designed for each of the various groups of engineers and should take account of the academic background formed by the main subjects as well as the objectives of the courses as a whole.

(2) No course can be comprehensive and it is better, by selection, to present a few basic ideas in a stimulating way than to give a treatment so full that it amounts to little more than a catalogue.

(3) For reasons stated in (1) clear cut and definitive syllabuses cannot be laid down, but there are several ways of handling the subject matter so that it is attractive, modern and coherent; three of these ways have been given as examples.

Three further comments may be helpful to those engineers and metallurgists who study this problem of teaching.

First, as regards textbooks: it is doubtful whether engineers will find a more useful book than that written by E. C. Rollason, although it was published as long ago as 1939 and its second edition appeared in 1949. Its 339 pages are written in words easily understood by engineers and contain a great deal of very practical information. For larger books on metals and other materials one would do well to look at those which have appeared in America during the past five years, but they are the work of large teams of contributors, whereas Professor Rollason's book was his own work in the decade after he left Birmingham with his first degree in metallurgy.

Secondly, as regards descriptive courses: The earlier courses had in them much descriptive matter which must still be essential background to engineers' knowledge of metallurgy. However, much of this can now be given better and more rapidly by means of the excellent coloured films nowa-days produced by industry after industry, often for the education of their own staff. Steel, copper, zinc, tin, nickel and their alloys may be described in this manner.

Such coloured technical films might well be run through twice for serious teaching purposes, the lecturer speaking about the

metal and the processes illustrated in the film between the first and second showing of the film and the students being expected to make their own notes. Such sandwich film-lecture-film sessions could be much more interesting and instructive than the old lantern illustrated lectures.

Thirdly, one may find it informative to approach this subject of teaching metallurgy to engineers by inquiring, "What do engineers wish to be taught about metals?" and examining the indexes of the leading Institutions. Metallurgists may be surprised to learn in this way that in the past thirty years The Institution of Civil Engineers asked a dozen or more metallurgists to lecture to them. Four were asked to speak about corrosion, three about rails, two about shock tests, two on steels, one on sources of information.

## Powder Metallurgy

The December meeting of the Powder Metallurgy Joint Group, the membership of which is restricted to those who are members of either the Iron and Steel Institute or of the Institute of Metals, was held at Church House, London, S.W.1, on Thursday and Friday, December 15 and 16, last. This was in accordance with the already known plan to meet formally twice a year (See THE ENGINEER, September 25, 1959, page 303) and on this occasion the meeting was divided into three sessions.

"*Sintered Stainless Steel.*"—On Thursday afternoon the theme was sintered stainless steel, and the two papers which were presented for discussion were already available in print (see *Powder Metallurgy*, No. 5, 1960, pages 85-115), both being written by R. L. Sands and J. F. Watkinson. They dealt first with the influence of alloy composition upon compacting and sintering behaviour and secondly with the properties of stainless steel powders sintered in dissociated ammonia.

"*Practical Aspects of Pressing Metal Powders.*"—On Friday the morning and afternoon sessions formed a symposium on the practical aspects of pressing metal powders, and this was based on fourteen papers, one of which has already been printed in *Powder Metallurgy*, No. 5, pages 130-148; all the other papers will be published in No. 6. The wide spread of interest in this subject and the way in which *Powder Metallurgy* has already earned what is probably the largest circulation in the world, of any periodical devoted to this specialist field, may be judged from the geographical origins of these fourteen papers. They come from Sweden, New Mexico, and Ohio, across the seas and from the United Kingdom.

*Plans for the Future.*—Engineers especially interested in this specialist subject will be glad to know that plans are well in hand for future meetings of the Powder Metallurgy Joint Group. Their Spring Meeting in 1961 is to be held at the Royal Commonwealth Society, Northumberland Avenue, London, W.C.2, on April 17 and 18. On the afternoon of the first day three specially invited review papers will deal with techniques for the evaluation of powders. The whole of the second day is to be devoted to discussing the relationship between properties of powders and their pressing and sintering behaviour. Their Winter Meeting in 1961 is to discuss sintered materials for high-temperature service, and planning still further ahead their Spring Meeting in 1962 has for its principal subject for discussion, disperse-phase-hardened systems, and for this offers of papers describing original, unpublished work are invited.

# Industry and the New Rating Bill

By P. G. MARSON*

THE latest Rating and Valuation Bill received its second reading on November 30, and is now in Committee. The Bill has twenty-five clauses and five Schedules. So far as industry is concerned the more important clauses are clauses one, two and five in Part I of the Bill. Although there are others which will affect industry to a greater or lesser degree, notably clause three and clauses fifteen to nineteen, they change the method of valuation only. Clauses one, two and five on the other hand alter the proportions in which the different classes of ratepayers are liable.

Out of the fourteen clauses in Part I of the Bill no less than eight give the Minister power to make Orders. Moreover, some of these Orders, and particularly those which will be made under clauses two and five, are substantially more important than the clauses. In fact they will contain the heart of the matter. The practical result is that a reading of the Bill does not make it possible to calculate exactly what the effect of these clauses is going to be. This is not just because the Orders have not been made. The point is that nobody is wise enough to foretell what will have happened between 1939, or 1956, and 1963 to the values upon which rating liability is based. The Order for clause two cannot be made until 1963 at the earliest.

What are the provisions of the clauses? Clause one ends the present 50 per cent derating relief given to industry and freight transport. Clause two gives the Minister power to reduce the rateable values of dwelling houses from 1963 to 1968, the first valuation period under the new provisions. Clause five gives the Minister power to make an Order exempting from valuation movable plant within size limits which he will prescribe. This article is confined to a discussion of the effects of these clauses. Clause three gives the Minister power to prescribe new methods of valuation for hereditaments formerly valued on the basis of accounts, royalties, receipts or profits. This may affect the method of valuing such diverse properties as mineral undertakings, licensed premises, cinemas and theatres, and racecourses. The intention of the clause is simplification of the method of valuation and no more. Part II of the Bill, clauses fifteen to nineteen, and the second and third Schedules provide a new method of valuing statutory water undertakings. Again, the aim is to simplify valuation.

To consider the main effects of the Bill upon industry it is necessary to look at clauses one and two together. However, there are one or two observations to make about clause one alone. There can be no doubt that industrial derating has few real supporters nowadays. A quick reading of the press at the time of the introduction of the Bill would show that. Even the Second Reading debate in Parliament produced little support. Two main reasons for this change in opinion since derating was introduced in 1929 are the recent prosperity of industry generally, full employment and, what is more closely related to rating as such, the passing of the belief that "factories are not a proper measure of ability to pay" because local government provides many services of a kind which cannot be related to their needs. It is probably fair to say that rating is now taking its place purely as a system of raising revenue generally for the purposes of local government. Industry therefore has the serious practical problem to face of securing more representation in local government. When introducing the Bill for its Second Reading the Minister said: "If, however, one effect of the Bill was to induce businessmen and industrialists to take a larger interest in local government, that, in my view, would be all to the good. Far and away the most expensive local government service is education. It is the education service which is outstandingly valuable to industry because our competitive power so largely depends on mental and technical ability. More businessmen ought to stand for election . . . . and they ought to encourage their staffs to do so." As other members pointed out, however, it may, in fact, be extremely difficult for industrial representatives to secure votes in any given locality where other interests will usually predominate both in area and voting power.

Owing to changes in values which will have taken place up to 1963, it is impossible to calculate exactly the effects of clauses one and two upon industry. Indeed, so many assumptions have to be made in order to make any estimates about the future position, that it can frankly be said that one is simply guessing. However, if the assumptions are clear, the estimates may be of use in showing the nature of the problem and the kind of things that could happen. The following calculations may provide the reader with the means of making his own, more acceptable, estimates! The first step in attempting to estimate the future position is to find out what has been happening in the past. The table below shows in round figures the actual rating position since 1955. The rateable values of each class of property and their respective percentage shares in the total can readily be seen.

The table shows the changes brought about by the 1956 revaluation of domestic property

*Changes in Rating Position Since* 1955

| | 1955 | | 1956 | | 1957 | | 1958 | | 1959 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | £m | Percentage | £m | Percentage | £m | Percentage | £m | Percentage | £m | Percentage |
| Industrial and Freight Transport | 16·0 | 4·4 | 40·6 | 6·5 | 41·4 | 6·9 | 41·6 | 6·8 | 79·7 | 11·6 |
| Shops and commercial ... ... | 39·4 | 10·7 | 174·0 | 28·0 | 139·0 | 23·1 | 142·0 | 23·3 | 147·0 | 21·4 |
| Domestic... ... ... | 219·2 | 59·8 | 307·8 | 49·4 | 315·0 | 52·4 | 320·9 | 52·6 | 327·4 | 47·6 |
| Miscellaneous* ... | 77·2 | 21·0 | 85·0 | 13·7 | 78·0 | 12·9 | 77·0 | 12·6 | 104·0 | 15·1 |
| Crown ... ... ... | 15·2 | 4·1 | 15·0 | 2·4 | 28·0 | 4·7 | 29·0 | 4·7 | 30·0 | 4·3 |
| | 367·0 | 100·0 | 622·4 | 100·0 | 601·4 | 100·0 | 610·5 | 100·0 | 688·1 | 100·0 |

* Federation of British Industries. The views expressed are not necessarily those of the Federation.

* Miscellaneous includes licensed premises, public utilities, education and cultural, entertainment and recreational, &c., truly miscellaneous. Many of these were abated.

to 1939 values and of industry and commerce to (then) current values. It also shows the effect of the rerating of industry in 1958 to 50 per cent from 25 per cent. In 1955 domestic properties bore about 60 per cent of the total burden, industrial and freight transport 4·4 per cent and shops, &c., 10·7 per cent. The effect of the revaluation in 1956 was to increase the industrial share by 50 per cent, the share of shops, &c., by 155 per cent and to decrease the domestic share by 17 per cent. One of the results of this change in shares was the 20 per cent relief granted to shops, &c., in 1957. The partial rerating of industry in 1958 resulted in an increase in the industrial share of rates of about 71 per cent, a very small decrease in the share of shops, &c., and a decrease in the domestic share of 10 per cent. Over the whole period 1955 to 1959 the shares have altered as follows : industry and freight transport 63 per cent increase ; shops, &c., 50 per cent increase ; domestic 20 per cent fall. Rateable values have altered as follows : industrial, 125 per cent increase ; shops, &c., 136 per cent increase and domestic 33 per cent increase. The next table attempts to show what might happen to rateable values and to the shares in the total rateable value in 1963. It is assumed that the revaluation will be achieved by applying increase factors of the size shown in the left-hand column for each class of property. Further, it is assumed that those increase factors will be applied, not to 1959-60 values, but to 1959-60 values as they will have naturally increased. The amount of this natural increase is, of course, another assumption.

The increase factor of 3 for domestic properties may, strictly speaking, be too small when it is remembered that twenty-four years will have gone by before the revaluation takes place. However, 3 has been the number most often used in the press and in Parliament and so it is used here. The totals for domestic properties and for shops are lower than they should be by an amount which is intended to take into account the fact that some properties in these classes are not derated and some receive smaller deductions than the standard. In the right-hand side of the table it will be seen that Miscellaneous and Crown rateable values have been increased. This increase is intended to allow for the derating or equivalent relief which some of these properties receive at present.

It will be evident that the results will take on a different appearance when local figures are substituted for national figures. Clearly the mixture of properties in any given locality will affect the figures.

In this table (from the industrial point of view) the 1963 figures show a " high " and a " low " estimate side by side. The low estimate is nothing more than multiplying industrial by 2, adding a fifth to shops and multiplying domestic by 3. The high estimate on the other hand allows for a natural increase in values as well. The right answer may be between the two figures, but nearer the higher than the lower.

*Estimated Position in Three Administrative Counties in* 1963 *Compared with* 1960

| | 1960 | | 1963 | | | |
|---|---|---|---|---|---|---|
| | Rateable value | | Rateable value " low " | | Rateable value " high " | |
| | £m | Per cent | £m | Per cent | £m | Per cent |
| **Middlesex :** | | | | | | |
| Industry and freight transport | 5 | 11 | 10 | 9·6 | 17·5 | 14·2 |
| Shops and commercial | 12 | 27 | 14·4 | 13·8 | 25·2 | 20·4 |
| Domestic | 26 | 58 | 78 | 74·7 | 78 | 63 |
| Crown | 2 | 4 | 2 | 1·9 | 3 | 2·4 |
| | 45 | 100 | 104·4 | 100·0 | 123·7 | 100·0 |
| **Lancaster :** | | | | | | |
| Industry and freight transport | 4·4 | 17·4 | 8·8 | 15·4 | 15·4 | 22 |
| Shops and commercial | 7·0 | 27·7 | 8·4 | 14·7 | 14·6 | 20·9 |
| Domestic | 13·0 | 51·6 | 39·0 | 68·5 | 39·0 | 55·7 |
| Crown | 0·8 | 3·3 | 0·8 | 1·4 | 1·0 | 1·4 |
| | 25·2 | 100·0 | 57·0 | 100·0 | 70·0 | 100·0 |
| **Durham :** | | | | | | |
| Industry and freight transport | 2·4 | 25·0 | 4·8 | 21·3 | 7·5 | 27·6 |
| Shops and commercial | 2·0 | 20·2 | 2·4 | 10·7 | 3·6 | 13·3 |
| Domestic | 5·2 | 53·7 | 15·6 | 67·6 | 15·6 | 57·7 |
| Crown | 0·1 | 1·1 | 0·1 | 0·4 | 0·4 | 1·4 |
| | 9·7 | 100·0 | 22·9 | 100·0 | 27·1 | 100·0 |

*Estimated Position in* 1963

| | Assuming revaluation but no rerating | | | Assuming revaluation and rerating | |
|---|---|---|---|---|---|
| | Increase factor (1) | Rateable value—£m | Per cent total | Rateable value—£m | Per cent total |
| Industrial and Freight Transport | 1·75 × £84m | 145 | 8·2 | 281 | 14·0 |
| Shops and commercial | 2·0 × £164m | 328 | 18·5 | 386 | 19·2 |
| Domestic | 3·0 × £353m | 1,059 | 59·8 | 1,059 | 52·8 |
| Miscellaneous | 1·5 × £114m | 171 | 9·6 | 195 | 9·8 |
| Crown | 2·0 × £34m | 68 | 3·9 | 85 | 4·2 |
| Totals | | 1,771 | 100·0 | 2,006 | 100·0 |

Note : (1) The sum multiplied by the appropriate increase factor is higher in each case by an assumed amount of " natural " increase in rateable values from 1959–63.
(2) The Domestic and Shops totals are rather less than multiplication by two or addition of one-fifth would give since some properties are not derated at all and some receive smaller deductions. Miscellaneous and Crown are increased by an amount to take into account some derating or equivalent relief which some of these properties receive.

It is hoped that the tables herewith will give some idea of the issues involved in revaluing and rerating in 1963. They should certainly show how difficult it is at present even to guess what will happen. The two most material factors are what will be the increase factor for domestic properties and what, to offset this, will be the increase in the values of industrial and commercial properties.

Householders have had many champions because their burden will increase the most. But one could hardly expect it to be otherwise. Nevertheless it has been thought necessary to give the Minister power to soften the blow. This power is contained in clause two of the Bill. Of course householders may be hard hit if, as seems likely, their rate bill goes up as well as their share in it. Furthermore, as has frequently been pointed out, householders must pay rates out of net income whereas industry can deduct rates for the purposes of national taxes.

But it might perhaps have been better to give individuals some national tax relief instead of carrying forward an anomaly in the rating system. When the Minister exercises his relieving powers under clause two he will by so much increase the shares of the other ratepayers. When will he do this ? In the debate on the Second Reading of the Bill the Parliamentary Secretary to the Ministry of Housing and Local Government said that the Minister would not be happy to see the domestic burden increase by as much as one-third without derating. If the fears of most people are right then the Minister will certainly have to use his power, perhaps to the tune of about 20 per cent relief. On the national figures above there would no need for an exercise of the powers, but on the local figures the true position is clearer : that the higher the proportion of industrial and commercial property in an area the more likely will it be that relief will be needed. But this again will depend on the change in industrial and commercial values in those areas. Therefore, the result could be that where industry and commerce predominate, other things being equal, they will have their share of the burden increased as a result of clause two.

This raises again the problem of representation for industry and makes it perhaps even more important. In Parliament when introducing the Bill on Second Reading the Minister said that he could give industrialists the assurance that the temporary derating of householders was designed to last for the 1963-1968 rating period only. But there will be a new Parliament in 1966-67 and it is possible that the higher the relief given to householders in 1963 the higher will be the pressures for its continuance in 1968.

Clause five of the Bill raises a subject of particular significance to the engineering industry : the rating of plant and machinery. This topic is calculated to create controversy even among industrialists. As between some industries, that is, between those who use a great deal of process plant and machinery and those who use none, the result may be some discrimination, for in the former there is heavier rating of the tools of trade.

However, there are industries, notably the furniture industry, where space is essential to production and sales. On these industries, too, rates bear heavily and so one might expect them to be less sympathetic to the arguments for the removal of process plant and machinery from rating. However that may be, there is a fundamental difficulty in the present rating of plant and machinery which it may fairly be said is tending to work to the disadvantage of industries with a great deal of plant and machinery. The problem is rooted in the legal definition of rateable plant and machinery and in the interpretation of that definition by the Courts.

To find out what plant and machinery is rateable it is necessary to look at Section 24 and the Third Schedule of the Rating and Valuation Act, 1925, and the latest Plant and Machinery (Valuation for Rating) Order. Those parts of the Act and the original Order of 1927 were based on the recommendations of two Committees both of which sat under the chairmanship of Sir Edward Shortt, K.C. However, the only part of this legislation which has raised the particular problem involved is contained in the Heading to the fourth class of rateable plant and machinery in the original Plant and Machinery Order (and in the recent 1960 Order). The fourth class itself consists of a list of plant and machinery and the Heading is a general introduction to, and limitation of, the list. It reads: " The following parts of a plant or a combination of plant and machinery (are

rateable) whenever and *only to such extent as any such part is or is in the nature of, a building or structure*." The words in italics have caused the difficulties. Industrialists have always maintained that machinery which can be described as movable, or as being capable of being moved, cannot at the same time be " in the nature of a building or structure." The Courts have not accepted this limitation (see, e.g. the leading case on the matter : *Cardiff Rating Authority v. Guest, Keen, Baldwin's Iron and Steel Co. Ltd.* 1949 IKB 385. There have been several cases on the same lines since then).

In 1957 a Committee was set up under the chairmanship of Sir Edward Ritson, K.B.E., C.B., to review the interpretation of the Plant and Machinery Order and to recommend any changes in its interpretation. The Committee examined with great care the intention of Parliament in enacting the legislation about the rating of plant and machinery. In their Report they say : " It appears to us that the general intention of Parliament was to derate process plant and machinery, with the important exception of plant and machinery which is of such a nature that it ought properly to be considered as part of the hereditament . . . . The test laid down in the Act is that, to be rateable, plant or machinery must be, or be in the nature of, a building or structure. In our view this is not so much an end in itself as a means to the end of deciding what kind of plant and machinery can properly be regarded as part of the hereditament."

In its Report the Committee recommended, among other things, as to the controversial Heading of the 1927 Order :

(1) That ancillary moving parts should not be rated.

(2) That power-operated plant which moves or rotates should be exempt.

(3) That small movable items of plant should not be rated.

These recommendations brought about a curious result, for it appeared that the Committee were without the power to make proposals (2) and (3) and that therefore they could not be carried into effect until the Minister could find the opportunity to legislate. Clause five of the new Bill is the result. However, yet another curious situation appears ! In Parliament, on Second Reading, the Minister said: " Clause five gives effect to two recommendations of the Ritson Committee . . . . effect was given to *all the rest* of its recommendations in the Plant and Machinery (Rating) Order 1960. But *these two outstanding* recommendations could not be given effect in that Order because they required amendments of the law."

The curiosity is, that if a comparison is made of clause five of the Bill, the Ritson recommendations, the 1960 Order and that statement by the Minister, it will be seen that the clause itself, although it is in two parts, covers only one of the outstanding recommendations. The proposal that power-operated plant which moves or rotates should be exempt is not included. Thus clause five on the face of it does not go as far as industrialists might have expected. Furthermore, the actual size and weight of plant and machinery which will be exempted by the Order made under clause five is not yet known. It is to be hoped that the limits will be at least those suggested by the Ritson Committee :

" Any item of plant or combination of plant and machinery excluding foundations, settings and supports which it is the practice of the trade in which such plant or combination of plant and machinery is used to move as required from one part of a hereditament to another or from one hereditament to another, not exceeding twenty tons in weight, or fifty feet in its longest dimension, or ten thousand cubic feet in volume measured from external dimensions."

On the more general question whether process plant and machinery ought to be exempt from rates, the Committee could make no recommendation, for it was not in their power. But they pointed out that the rates paid on plant and machinery are about £12,000,000. They also had information that the incidence of such rates varies widely from industry to industry.

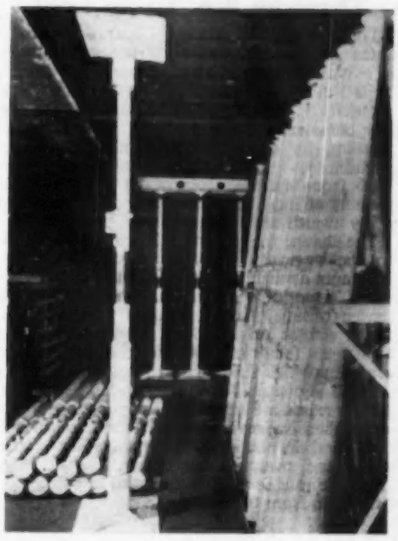
This wider issue of the rating of process plant and machinery needs a more thorough, factual, examination. Undoubtedly, the case for exemption has great merits, as two members of the Ritson Committee said, but the opportunity for action seems to have been missed. In summing up the effects of this Bill on industry it must be admitted that it is too early to say with any certainty at all what will happen, nationally or locally. Certain things stand out : the Bill's provisions will bear most heavily on basic industries such as shipbuilding, which can hardly bear any increase in costs and which will nevertheless receive a particularly large valuation owing to its use of considerable amounts of rateable plant and machinery. There are other " marginal " situations in more prosperous industries of which engineering provides examples. Engineering firms of all kinds contribute a great deal to the export trade which will certainly continue to be highly competitive. Any increase in costs, whether passed on or not, may be significant. In general, the pressure on costs and therefore on prices is tending to rise. There are certain localities in which an increased rate burden on industry may be more serious. New industries are, for example, being attracted to the North West. Among these engineering will play an important part. The same is true of new towns to which light engineering firms may be attracted. It is impossible to say by how much their rate bill will increase but, certainly, any over-large concession to householders in those areas might unduly add to their burden. Finally, it must be remembered that an increase in rate costs is passed on and is cumulative. In this context the famous speech of Mr. Winston Churchill in 1928 might usefully be recalled :

" The burden of rates on industry is cumulative. Coal (rated) is converted into coke (rated again), and used with iron ore (rated) and limestone (rated) to make pig iron (rated again), and this, with more coal (rated) and other rated products, is used to make steel (rated again) . . . . Thus, at every stage in the progress of basic products till they finally reach the ship for export, or reach the home consumer, the rates add to the price irregularly, unequally, and injuriously."

## Hydraulic Pit Props for Temporary Floor Strengthening

An unusual and effective application for hydraulic pit props is their use for the temporary strengthening of the exhibition hall floors at Olympia, London, to enable very heavy exhibits to be moved and erected without damage to the floors and basement areas. This problem of the temporary strengthening of the Olympia floors was placed before Dowty Mining Equipment, Ltd., Ashchurch, Tewkesbury, Glos. It was required that the support reinforcement supplied could be erected at different places from time to time to permit heavy exhibits to be moved freely over the exhibition hall floor. Certain of the props then remain set beneath exhibits for the period of the exhibition. Between exhibitions the props occupy a minimum of space in wall racks to leave valuable basement accommodation available for storage purposes. Special handling equipment had also to be provided for raising heavy head beams to the basement ceiling for the props to be set beneath them and an existing mobile lifting truck was modified for this duty.

The Grand Hall of Olympia was erected before methods of steel reinforcement were embodied in



**Hydraulic props as used for the temporary strengthening of floors at Olympia in their installed and storage positions**

building structures and the floor girders over basement areas rest on brick supporting walls to which they are not secured. This means that when setting up hydraulic props, no up-thrust exceeding the weight of the floor can be tolerated and to ensure that the floor weight is not exceeded, pressure relief valves are incorporated in the props to limit the setting to ½ ton. Pressure gauges are fitted to confirm that each prop accepts its share of the total load.

To satisfy the L.C.C. district surveyor that the support system developed would comply with the stringent regulations, a trial was carried out with twelve props set at ½ ton pressure and during the test two mobile cranes totalling 20 tons in weight were parked on the hall floor immediately over the hydraulic supports. The indicators on the pressure gauges confirmed that without floor deflection the weight was transmitted to the basement floor and, when the two cranes were removed, the prop pressures returned to their original setting. At the conclusion of this test the district surveyor confirmed his general approval of the system. Our illustration shows typical settings of the prop supports and the way in which the props are stored when not in use.

[Reply Card No. E11131]

## Technical Report

*Elastic Semi-Infinite Medium Bounded by a Rigid Wall with a Circular Hole.* By S. Gravesen, Laboratoriet for Bygningsteknik, Danmarks Tekniske Hojskole, Copenhagen. Price Dkr. 6.00—Bulletin No. 11 of the Structural Research Laboratory, Technical University of Denmark, deals with the stresses set up in an elastic medium, the plane surface of which is subject to compression by a rigid wall with a circular hole. Radially about the axis of the hole, and in depth, the medium extends to infinity and contact is assumed to be complete ; additional assumptions are either zero transmission of shear at the interface or zero slip. Integral solutions are first derived for the load and for the deflections in the unloaded area, in terms of the deflections in the loaded area, under conditions of axially symmetric loading exterior to a circle. Next, the boundary is considered to be a rigid wall, and solutions are deduced for the reactions between wall and medium, and the deflections inside the hole, for arbitrary axially symmetric loading inside the hole. The last-mentioned solutions are applied to the following cases of loading : a single force, a circular line load, and a load uniformly distributed inside a circle.

# SHORTER REPORTS

## Electricity Bulk Supply Tariff

THE Central Electricity Generating Board states that it reluctantly finds it necessary to make an overall increase of approximately 2½ per cent in its Bulk Supply Tariff charges (under which electricity is sold to the Area Boards) for the year commencing April 1, 1961. The Board is pursuing its declared policy of progressively providing an increasing proportion of its capital needs from internal resources. It has also taken account of increased costs, including wage and salary awards and interest rates.

The change will involve a 3½ per cent increase on the normal fixed charge per kilowatt of maximum demand (raising it from 142s. to 147s.) and a 2½ per cent increase on the basic running charge (raising it from 0·41d. to 0·42d. per unit). There will be no alteration in the coal clause adjustment factor of 0·00055d. per unit for each penny by which the fuel cost per ton in the year shall be above or below sixty shillings per ton. The increases are interim adjustments pending a comprehensive review of the structure of the tariff, and do not imply any change in the long term trend towards a decreasing running charge, the basic rate for which over the last five years has fallen from 0·5d. per unit.

## Power Rise for "Dido" Research Reactor

THE research reactor "Dido" at Harwell has been loaded with a new core to give increased power, as described below. It will be recalled that "Dido" is used for the testing of materials and components for future reactor systems; it is also used for basic research and for the production of radioisotopes. The improvements to the core are designed to increase the number of experiments that can be loaded into the reactor at one time, since some of these experiments absorb a considerable proportion of the reactivity available.

The new "Dido" core consists of twenty-five hollow fuel elements with an increased uranium-235 content. The old plate-type fuel elements contained 115 grams of uranium-235 per element whereas the new design contains 150 grams of uranium-235 per element. Experimental rigs of up to two inches diameter can now be accommodated within the fuel elements in regions of extremely high fast-neutron flux. The modifications have increased the total number of available high-flux experimental positions from 27 to 52. The additional fast-neutron positions within the fuel elements will be of great value for high-dose irradiation damage studies of graphite, fuel canning materials and other materials for power producing reactors.

Originally "Dido" operated at a power of 10MW and had a maximum thermal neutron flux of about $2 \times 10^{14}$ neutrons per square centimetre per second. The modifications have increased the reactor power level to 13MW but the thermal neutron flux has remained substantially unchanged; the reason for this is that the power of a thermal reactor depends on the product of the mass of uranium-235 in the core and the magnitude of the thermal neutron flux. "Dido" was first run at low power using the new core on October 7, 1960. Full power operation began on November 18.

The modifications carried out and the start-up procedures were similar to those associated with the start-up of a completely new reactor. During the period of low-power running the reactor physics characteristics of the new core were fully remeasured, since such a major modification completely changes all the reactor physics parameters. The work was carried out by the engineers and physicists of the Research Reactors Division at Harwell.

The United Kingdom Atomic Energy Authority has three high-flux reactors used for testing reactor materials. Two of them "Dido" and "Pluto" are at Harwell and a third (D.M.T.R.) is at Dounreay. "Dido" was the first of these reactors to be commissioned. A similar modification to the core of the "Pluto" reactor will be carried out during 1961.

## Engineering and Shipbuilding Wages

THE claim of the Confederation of Shipbuilding and Engineering Unions for an increase of £1 a week for engineering workers was settled on Wednesday of last week, when the Engineering and Allied Employers National Federation increased its offer, made on Wednesday, November 23, (THE ENGINEER, December 2) by 1s. 6d. in each grade. This offer was accepted by the Confederation. The employers suggested that the increases should be paid from January 2, 1961, but under pressure from the unions, agreed to pay them from December 26, 1960.

The settlement will mean an increase in the consolidated time rates as follows: for the skilled grades 8s. 6d. per week; for the intermediate grades 8s. per week; for labourers 7s. 6d. per week, and for women 7s. per week. The increases will bring the basic minimum weekly rates in the engineering industry up to £9 15s. 2d. for skilled men, £8 4s. 10d. for unskilled men and £6 13s. 6d. for women of eighteen years of age and over. It is estimated that these increases will cost the industry about £60,000,000 a year.

A meeting between the Confederation of Shipbuilding and Engineering Unions and the Shipbuilding Employers Federation was also held later the same day, Wednesday, December 21. On Thursday, September 29, (THE ENGINEER, October 7) the Confederation asked the employers to give a "substantial increase" in wages to its employees, but on Wednesday, the employers still refused to offer any increase in wages. The Federation undertook, however, to consult its constituent associations about the possibility of making some concession, and to meet the unions again on January 9, 1961.

## Railway Electrification

THE following statement has been issued by the British Electrical and Allied Manufacturers' Association on behalf of the manufacturers.

"We share with British Railways concern at the inconvenience to the public occasioned by the difficulties in the introduction of the new electrification services in the Scottish and Eastern Regions. The manufacturers are using all their resources in collaboration with British Railways in solving the special technical problems which have arisen.

"British Railways and the manufacturers, working in partnership, are engaged in the introduction of railway electrification schemes employing the most advanced techniques under conditions which are not paralleled in any other country. The new high-voltage a.c. system has been adapted to British Railways with its densely trafficked suburban and main line services, heavy pollution conditions and special clearance problems in tunnels and station areas. More than 600 miles of lines have been commissioned on the high-voltage system in two months.

"It is a basic problem of major alterations to railway systems that complex works have to be carried out whilst maintaining full services. The new equipment was intensively tested by the manufacturers jointly with British Railways under trial running conditions, but with so many different factors involved the final proving is only possible when all the new equipment is operating together as one complete system.

"The fullest technical collaboration is being maintained between the manufacturers and British Railways, with every confidence that these particular difficulties will be quickly overcome. Britain's electrical engineering exports depend on technical progress and problems of this kind are part of the price to be paid for maintaining our leadership."

A public enquiry into incidents on the Glasgow suburban a.c. electrification involving explosions or slight fires in the transformers and conservators of five trains was opened on December 22 by Brigadier C. A. Langley, Chief Inspecting Officer of Railways. In adjourning the enquiry on December 23, Brigadier Langley said he had received assurances from the B.T.C. and from Associated Electrical Industries, Ltd. that they would do everything to find a solution to the failures as rapidly as possible. He would take the necessary steps if he decided to reconvene the inquiry in public.

## Kent Coast Electric Services

Electric trains will replace certain steam services on the Southern Region line between Dover, Minster and Ramsgate as from January 2. This is the first step in the second phase of the Region's Kent Coast electrification scheme, due for completion in June, 1962. The lines are being electrified at 750V d.c. with conductor rail supply, and it is likely that electric services will be introduced similarly on further sections as they are completed. The routes being converted in this second phase are Sevenoaks to Ramsgate *via* Ashford and Dover (of which the Dover–Minster–Ramsgate section forms a part), and the branches between Paddock Wood and Maidstone West; Maidstone East and Ashford; Ashford and Minster; and the Folkestone Harbour branch.

Electrification of the 45 track-miles (21¾ route-miles) between Dover, Minster and Ramsgate took about 14 months. Test trains began running at the end of October this year. Five substations and six paralleling huts have been provided for the power supplies and their control. Engineering work is being undertaken at Minster, Sandwich, Walmer and Martin Mill to enable eight-car trains to be dealt with.

## Microwave Frequency Checking Equipment

AMONG several new items of microwave apparatus announced by Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2, is a frequency checking equipment which is designed for the accurate measurement of microwave radio relay frequencies in the 3600–4200 Mc/s band. The unit, 74283-A, consists of a signal mixer into which the transmitter frequency to be measured is fed, and from which is derived an output frequency for measurement by an external heterodyne frequency meter.

The signal mixer comprises a crystal-controlled frequency multiplier and a signal mixing diode, the latter also functioning as a harmonic generator. The basic crystal frequency is 26·7483 Mc/s, which is multiplied to 1310·667 Mc/s by valves, and then to 3932 Mc/s in the harmonic generator. By feeding the s.h.f. frequency to be measured into the mixer diode, and taking the output from the diode through a 450 Mc/s low-pass filter, a signal is obtained for measurement by the heterodyne frequency meter. The frequency of the signal under test is 3932 Mc/s plus or minus the frequency meter reading. When used with systems operating in the C.C.I.R. or the 40/70 North American frequency allocation plans, it is known whether the signal under measurement lies in the ranges 3500–3927 Mc/s, or 3937–4300 Mc/s. Ambiguity as to whether the meter reading must be added to or subtracted from the known beat frequency of 3932 Mc/s is removed, because the difference frequency must be at least 5 Mc/s in order to be measured by the meter,

and this locates the signal in one or other of the known bands. Should any doubt remain, however, the frequency generated by the signal mixer can be shifted slightly in either direction. If, on its being increased, the heterodyne frequency meter reading decreases, the signal under test lies in the upper band, and *vice versa*. For measurements of system i.f. frequencies (70 Mc/s nominal centre frequency) the heterodyne frequency meter is used alone.

The equipment operates on power supplies of 90–265V, 45–66 c/s, single-phase a.c. Measurements of the signal mixer are 21¾in by 11¾in by 20in, and the weight 116 lb. Frequency stability of the 3932 Mc/s signal is within ±80 kc/s with a normal ambient temperature variation of ±20 deg. Cent., and the power is 1mW.

[Reply Card No. E11146]

## Pulse Code Modulation Telephony

EXTENDED field trials of pulse code modulation (P.C.M.) telephony are taking place on a working cable link between two telephone exchanges in Madrid. The system in use has been developed by Standard Telecommunication Laboratories, Ltd., London Road, Harlow, Essex, in conjunction with Standard Telephones and Cables, Ltd., and Le Matériel Téléphonique of Paris. For the purpose of the tests, a number of pairs in an existing 6 km length of 900-pair cable between the Norte and Delicias exchanges has been given over to P.C.M. transmission, most of the remaining pairs being kept in normal inter-office or other service. These facilities have been made available by the National Telephone Administration of Spain. The tests are being conducted with the co-operation of Standard Electrica, S.A., Madrid, an associate of S.T.L.

Although P.C.M. was invented over twenty years ago by A. H. Reeves, of Standard Telecommunication Laboratories, it has hitherto been associated mainly with specialised services rather than the normal telephone network. The equipment now on trial is serving to explore how P.C.M. principles can be applied economically and with minimum complication so that ordinary telephony circuits may benefit from increased capacity without the inter-circuit interference and noise that cannot be eradicated from time-multiplex systems with normal amplitude modulation.

In P.C.M. the speech from a number of sources is sampled at a given frequency and each sample is converted into a pulse code representing its instantaneous amplitude. Thus, instead of speech waveforms being transmitted, only a train of high-speed electrical pulses of uniform amplitude is sent, and it would require an exceptional ratio of noise to signal to mutilate the code. In the Madrid installation the speech from twenty-three subscribers is sampled in sequence 8000 times a second ; these samples are applied to a common coding unit. The coder compares the instantaneous amplitude of each sample with a scale having seventy intervals, decides in which interval it lies, and generates the appropriate code character.

The code consists of seven digits to represent each level and has been chosen to avoid the transmission of frequencies unsuited to normal cable and apparatus characteristics. The high frequencies used—about 1·5 Mc/s—result in cable losses being quite high so that frequent repeatering is necessary. For the trials, some routes have repeaters at 1 km spacing while on others repeaters are 2 km apart. The repeaters are, however, simpler than those normally used in telephone circuits, since they act only as pulse regenerators. Using transistors and consuming low power, they are readily supplied over the light-gauge telephone cable itself.

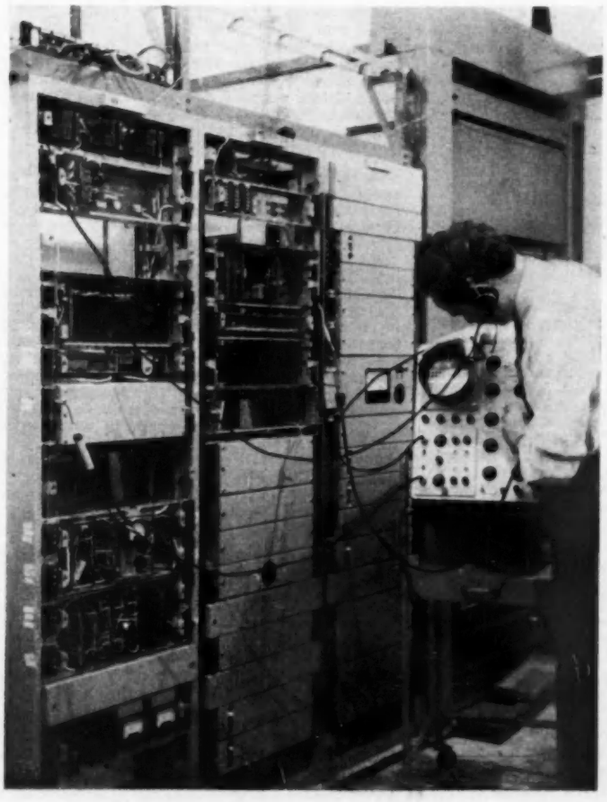
At the receiver a decoder turns the code pulses back into pulses of varying amplitude which are then reconstituted into speech and distributed to twenty-three circuits. The reconstituted speech is not an exact replica of the original ; it is an approximation, since the amplitudes of the samples are measured against a 70-level scale, but the effect can only be detected even by a discriminating ear if the P.C.M. is directly compared with a short, direct connection. Moreover, this effect does not accumulate along the route. The pulses can be detected in spite of interference and regenerated at each repeater, so that on long or noisy routes the overall quality is better than with a direct voice-frequency connection.

The transmission system operates on a four-wire basis (send and receive channels on separate pairs), but increases ten-fold the traffic capacity of existing two-wire (send and receive channels on same pair) cables or the cheapest types of new cables. It is expected that this system will be particularly compatible with time-division electronic exchanges. A code signal, once generated, could be routed through several transmission paths and switching centres, being converted to speech only when quite near its destination. The speech quality would then be uniformly good, regardless of route or distance.

In the accompanying illustration of terminal equipment at the Delicias exchange, the three bays of the rack, from left to right, accommodate the receiver, the transmitter, and the power supplies. Incoming signals are fed into the top unit of the receiver bay, which is a terminal regenerator, so that pulses are " cleaned up " also at this stage. Two distribution panels occupy the middle of the bay, providing the connections to the telephone circuits through plug-in printed cards. Below these are the decoder unit and, at the bottom of the bay, the synchronising panel.

The tests in Madrid will enable experience to be gained in the choice of pulse codes and coding levels for acceptable speech in normal telephony. Research in the method of transmission by the Post Office at Dollis Hill (see our October 7 issue, page 592) is using an eight-digit code for representing 256 voltage levels.

[Reply Card No. E11151]



**Terminal equipment of inter-exchange P.C.M. telephony link in Madrid**

## Punched Paper Tape Reader

A HIGH-PERFORMANCE punched paper tape reader, originally designed for use with the " Deuce " computer, is now being manufactured as standard equipment by The English Electric Company, Ltd., at the company's Data Processing and Control Systems Division, Kidsgrove, Staffordshire. The reading speed is up to 1000 characters per second, and the tape can be stopped from full speed after reading any character, without losing the next. It can be started and stopped to a maximum of thirty times per second. An adjustment is provided to accept tapes of standard widths with five, seven, or eight code holes, and tape may be used from any stock, subject to certain limitations on translucency.

Magazines are available for fitting to the machine to allow repetitive reading of a loop of tape up to 100ft in length, or to accommodate up to 300ft of free tape which may then be easily rewound from the trailing end. Magazines are easily interchangeable and any number can be supplied for use with a reader. A replaceable plugboard allows rearrangement or omission of the bits within a character as read from the tape. Switches are provided which allow the operator to select odd or even parity checks or no check, and which cause any " all ones " character to be ignored. The reader uses only transistor circuits ; the sensing elements are phototransistors which are compensated for temperature variation.

High-speed readers are now operating as part of six " Deuce " installations, including those at Glasgow and Liverpool Universities, and further orders are in hand. The reader is being fitted to the KDF 9 data processing system, and will provide a main channel for manually prepared data and programmes.

[Reply Card No. E11152]

## Secondary Radar

IT has been announced by the Ministry of Aviation that the Federal Aviation Agency and the Ministry have had technical discussion and have reached agreement as to compatible technical characteristics of secondary surveillance radar and side lobe suppression. Each will shortly issue its national standard and technical characteristics. Secondary surveillance radar consists basically of a ground/air interrogation radar which elicits coded reply signals from a transmitter-receiver in an aircraft. When an aircraft comes into the beam of the secondary radar the aircraft transmitter automatically sends out a signal which enables the plane to be identified and its bearing and range determined. The first secondary radar equipment in Europe for civil aviation was recently installed at London Airport for operational trials.

# PERSONAL AND BUSINESS

## Appointments

B.T.R. Industries, Ltd., announces the appointment of Mr. A. Kennaway as controller of technical operations.

MR. A. W. PAGE has been appointed sales director of Brookhirst Igranic, a member of the Metal Industries Group.

MR. C. C. MILLER has been appointed by The Delta Metal Company, Ltd., as deputy chairman of Earle, Bourne and Co., Ltd.

MR. W. LATTA has been appointed director and general manager of Rhodes, Brydon and Youatt, Ltd., following the acquisition of the company by Crane, Ltd.

THE MINISTRY OF AVIATION announces the appointment of Sir Walter Edmenson to the board of British European Airways for a further period of two years from December 16, 1960.

SIR WILLIS JACKSON, F.R.S., has accepted the invitation of the Association of Supervising Electrical Engineers to become president. He will be installed as president on January 17, 1961.

MR. J. IVAN SPENS has retired from the board of directors of John Summers and Sons, Ltd. Mr. Stephen A. R. Gray and Mr. Peter J. Summers, assistant general managers of the Shotton Works, have been appointed directors of the company.

THE ROYAL SOCIETY announces the appointment of the following vice-presidents for the year ending November 30, 1961 : Sir Alexander Fleck, Sir Lindor Brown, Sir William Hodge, Sir Patrick Linstead, Professor T. M. Harris and Dame Kathleen Lonsdale.

THOS. P. HEADLAND, Ltd., Melon Road, London, S.E.15, has announced the appointment of Mr. R. J. Watson to its sales staff. He will cover the counties of Berkshire and Buckinghamshire in place of Mr. E. A. Irven who has transferred to the subsidiary company, Headland Engineering Developments, Ltd.

MR. C. R. WHEELER, chairman of Guest Keen Iron and Steel Company, Ltd., additional vice-chairman of Associated Electrical Industries, Ltd., and a director of The Steel Company of Wales, Ltd., will succeed Mr. R. F. Summers, chairman of John Summers and Sons, Ltd., as President of the British Iron and Steel Federation on January 1, 1961.

THE BRITISH TRANSPORT COMMISSION announces the following appointments : Dr. L. C. F. Blackman has been appointed assistant director, chemical services division, Muswell Hill, Research Department ; Mr. T. S. Hough has been appointed assistant projects development engineer (design), Stooperdale Works, Darlington, Mechanical Engineering Department ; Mr. J. K. Brown has been appointed principal scientific officer, Electric Traction Research Department.

## Business Announcements

J. C. BAMFORD (EXCAVATORS), Ltd., Lakeside, Rocester, Staffs, states that its telephone number has been changed and is now Uttoxeter 3122.

PAYNE PRODUCTS INTERNATIONAL, Ltd., states that its address is now Buckingham Avenue, Trading Estate, Slough, Bucks (telephone Slough 26741-4).

MR. A. R. GREEN, general manager of Magnet Works of The General Electric Company, Ltd., is retiring on December 31, after forty years' service with the company.

BLAW KNOX, Ltd., states that with effect from January 1, 1961, its head office will be located at Thorn House, Upper St. Martin's Lane, London, W.C.2 (telephone Temple Bar 0381-6).

GOODYEAR PUMPS, Ltd., a Holman Group Company, has appointed Firma Willi Grassel of Bad Oeyn-Hausen as main distributor for Goodyear pumps in the German Federal Republic.

THE FIRTH CLEVELAND GROUP has formed a new company, Firth Cleveland Steel, Ltd., with registered offices at Wentworth Street, Sheffield. The company will operate from Holmes Mill, Rotherham. The chairman is Mr. C. W. Hayward, chairman of Firth Cleveland, Ltd.

THE FIRTH CLEVELAND GROUP has formed a new company named Firth Cleveland Steels Incorporated, with offices at 230, Park Avenue, New York 17, New York. It will act as selling agent in the United States for all the companies in the steels division of Firth Cleveland.

TELE-NOVA, Ltd., Autophone House, 73, Great Peter Street, Westminster, London, S.W.1, in association with Tempair, Ltd., of the Rootes Group, is providing an air-conditioning service on a full rental-maintenance basis, to be known as "Cleanaire Services." The service is initially confined to the Greater London area.

CHARLES CHURCHILL AND CO., Ltd., Coventry Road, South Yardley, Birmingham, has announced a further addition to the Group in the incorporation of Denham's Engineering Company, Ltd., of Halifax. Mr. Roy S. Denham, the chairman and managing director, will be retiring.

R. W. CRABTREE AND SONS, Ltd., 109, Borough Road, London, S.E.1, has established a subsidiary in the U.S.A. which will be known as R. W. Crabtree and Sons Inc., 56, Beaver Street, New York 4, New York. Mr. Norman Porter has been appointed vice-president of the new company.

THE VIKING PUMP COMPANY of Cedar Falls, Iowa, U.S.A., and ZWICKY, Ltd., Buckingham Avenue, Slough, Bucks, have concluded an agreement whereby Zwicky Ltd., acquires the exclusive rights to manufacture and sell in the United Kingdom the full range of Viking pumps.

MARCONI INSTRUMENTS, Ltd., St. Albans, Hertfordshire, under a recent agreement with Computer-Measurements Company of Sylmar, California, is to manufacture C.M.C's range of transistorised electronic computers, and will have world selling rights outside North America and Japan. The agreement covers a ten year period, and includes provision for the exchange of engineering information in the field of related transistorised products.

THOS. P. HEADLAND, Ltd., 10, Melon Road, London, S.E.15, announces that as a result of the continued expansion of the gauge and measuring instruments division of Headland Engineering Developments, Ltd., it has decided to set up a separate, wholly-owned, subsidiary company to design and manufacture screw and plain gauges, jigs and fixtures. The new company will be known as Headland Gauges, Ltd., 45-46, Lower Marsh, London, S.E.1.

CHLORIDE BATTERIES, Ltd., is transferring the major portion of its sales headquarters from London to the head office and principal manufacturing centre of the company at Exide Works, Clifton Junction, Nr. Manchester, on January 2, 1961. A London sales office which will care in particular for automotive equipment, government and dry battery business will be maintained at Grosvenor Gardens House until January 30, 1961, when it will be transferred to 137, Victoria Street, London, S.W.1 (telephone Victoria 2299). Mr. A. C. Stewart, sales manager, who is approaching retirement age, will not be moving North. He will be succeeded by Mr. M. A. Griffith-Jones on completion of the move but his services will be retained by the company in the capacity of consultant until he retires.

HAWKER SIDDELEY (HAMBLE) Ltd., will trade as Petters, Ltd., and will function as the Hamble Division of the company at Staines, with effect from January 1, 1961. Petter, Ltd., of Staines, will continue to manufacture and sell diesel engines of 1½ to 108 b.h.p. and the Hamble works to manufacture and sell diesel generators, marine auxiliary sets, transport refrigeration equipment, bus shelters and sheet metal products, and also to provide Petter and Armstrong Siddeley spares and service, including the rebuilding of engines for the Petter service engine exchange scheme. The production of catamarans has been transferred to the boat building section of SARO (Anglesey), Ltd., Beaumaris, Anglesey, N. Wales. Mr. J. C. Dacombe has been appointed to the board of Petters, Ltd., as service manager, and Mr. T. D. Turner has also joined the board with the duties of general manager, Hamble Works.

## Miscellanea

BRITISH TRANSPORT COMMISSION FILMS.—Distribution of films made by the British Transport Commission was at first directed mainly to cinema theatres, but simultaneously a wide non-theatrical distribution was developed and now amounts to about 1000 films a week. Films produced for this purpose tend to be more specialised than those designed simply for selling railway passenger services or keeping the public informed of what the railways are doing. Three recent subjects in this category are "Railway Electrification at Industrial Frequency," "Speaking of Freight" and "Second Report on Modernisation." All are in "Eastmancolour" and available in 35mm and 16mm sizes. The electrification film was first shown at the British Railways Electrification Conference in October and will have continuing use with industrial audiences and technical colleges and as an introductory film for new recruits to the electrical engineering staffs of British Railways. Arrangements are also being made for its showing overseas by British manufacturers of railway equipment. Animated drawings are used freely and effectively to demonstrate features of the power supplies and traction equipment. "Speaking of Freight" stages a discussion between an industrialist considering enlisting railway service for a food products distribution scheme, and the railway commercial representatives. It is expected to be valuable in training for railway salesmanship as well as for showing invited audiences of business and industrial executives the scope of railway freight facilities, especially in container service. "Second Report on Modernisation" follows an earlier film on the same theme which has been seen already by at least 3,000,000 people. It places particular emphasis on freight services, new depots and marshalling yards, and includes shots of the latest road-rail vehicle.

FOURTH INTERNATIONAL CONGRESS ON PRESTRESSED CONCRETE.—The Prestressed Concrete Development Group has announced that the Fourth International Congress of the Fédération Internationale de la Précontrainte will be held in Rome and Naples from May 27, to June 2, 1962. The following subjects will be discussed : "Results of research with special reference to durability and fatigue." ; "Site considerations (problems and difficulties remedies and solutions)." ; "Economics of prestressed concrete in relation to regulations, safety, partial prestressing, lightweight concrete, &c." ; "Progress in precast factory manufacture and standardisation." ; "Outstanding structures in prestressed concrete construction" : (*a*) bridges, viaducts and elevated roads ; (*b*) buildings and other structures.

DEMONSTRATING THE PELTIER EFFECT.—In order to demonstrate the generation or absorption of heat at the junction of two conductors by the Peltier effect, Salford Electrical Instruments, Ltd., is marketing a unit specially designed for use in schools, universities and teaching laboratories. The S.E.I. unit has a single thermojunction of "p" and "n" type bismuth telluride connected to a large heat sink consisting of two cooling fins. The cold junction is formed by a plated brass mirror soldered to the bismuth telluride blocks. Both the temperature of the mirror and the output voltage can be measured. Maximum current rating of the new unit is 10A. With this current, which can be supplied by a 2V accumulator, it is possible to freeze a drop of water on the mirror and grow hoar frost from the atmosphere. The unit may also be used as a dew point hygrometer.

INTERNATIONAL CONFERENCE ON MACHINE TRANSLATION OF LANGUAGES AND APPLIED LANGUAGE ANALYSIS.—The Autonomics Division of the National Physical Laboratory announces the convening of an international conference on Machine Translation of Languages and Applied Language Analysis, to be held from September 5 to 8, 1961, at the Laboratory, Teddington, Middlesex. Written contributions to the conference are invited from workers engaged directly in research into the machine translation of natural languages and also from those who are concerned with the syntactic or semantic analysis of languages, where such analysis may be of help in achieving machine translation. The conference will take place in the new N.P.L. Conference Centre, which has a main hall to seat 400 with provision for relay of simultaneous translations of proceedings. Details of the programme and of arrangements for registration of delegates will be announced in the Spring of 1961.

## Award

THE COUNCIL OF THE ROYAL SOCIETY has accepted an offer by the Trustees of the Leverhulme Trust Fund to mark the occasion of the Royal Society's Tercentenary, by the award of a gold medal. Under the terms of the offer the medal is "for award by the Society, every three years, to the individual who in the opinion of its Council shall have made the most significant contribution in the field of pure or applied chemistry or engineering including chemical engineering. The medal, which will be in gold, will be accompanied by a monetary award of £500." The Council has made the first award of the medal to Sir Cyril Hinshelwood, O.M., F.R.S., who retired as President of the Royal Society on November 30 last, for his outstanding contributions to physical chemistry.

# CONTINENTAL AFFAIRS

*by Our Continental Editor*

## 125th Anniversary of German Railways

ON December 7, 1835, the "railway age" began in January with the inauguration of 6km-long line between Nuremberg and Fürth. The train, which covered the distance in fifteen minutes, was hauled by the locomotive "Adler" built in Great Britain by Stephenson, and driven by William Wilson. This locomotive had a service speed of 23km.p.h., and reached 40km.p.h. in trial runs, i.e. not quite yet the speed of its namesake, the eagle. This was accomplished already sixteen years later, when a German-built locomotive succeeded in attaining 112km.p.h. (That engine, contrary to custom, did not bear a name, as the record-breaking run had taken place before its official delivery to the railway.)

The "Adler" was scrapped in 1857 after twenty-two years' service, but replicas of the engine and train were built in 1934 for the centenary celebrations. It was this which was exhibited at the "Schiene und Strasse" transport show held at Essen from September 10 to 25 (Fig. 1) and also at the recent festivities marking the 125th anniversary when a repetition of the original journey was staged. It is of interest to record that goods were not transported until seven months later: on July 11, 1836, two barrels of beer were sent to the railway inn at Fürth, and this traffic continued if space on the trains was available.

The main impulse to the development of the railways in Germany, as elsewhere, came however precisely from the need to improve goods transport between the hinterland and the major towns which had been established along the rivers and so were connected by water with the sea and to some extent with one another.

The first state-owned railway in Germany, from Brunswick to Wolfenbüttel, was built in 1835–38 under the direction of Philipp-August von Amsberg (1788–1871) who directed the ducal railways until his retirement in 1870, when the railways were denationalised and sold to a private company closely connected with the Prussian railways which were then beginning to dominate Northern Germany. Already in 1824 Von Amsberg had suggested the building of a railway between Hanover and the Hanseatic seaports of Bremen and Hamburg, with connections at Celle and Hademsdorf for a branch line to Brunswick. These railways were to be horse-drawn and to use existing roads; even so, the cost of transport was estimated by von Amsberg to be one-seventh, and the transit time one-quarter of road-borne traffic. Prices for grain, timber, forest and mining products were at the time fixed at Hamburg and the other ports, with the result that the produce of the province could either not compete at all or was severely handicapped as compared with competition from further inland but which was able to use the waterway of the river Elbe.

### Electrification

A major advance, second in importance only to the invention of the steam locomotive, was the introduction of electric traction, based on the dynamo-electrical principle discovered by Werner Siemens in 1866, which soon led him to design the first electric motor. At the Berlin trade fair of 1879, Siemens demonstrated the first electric railway which was used to transport visitors in the exhibition grounds. However, the railway authorities did not yet consider electricity to be a serious competitor to steam since powerful main-line steam locomotives were already being made by Krupp, Borsig, Henschel and Krauss-Maffei, which moreover carried their own supplies of fuel and water, while transmission of electric power over long distances was still impossible.

However, the advantages of electric passenger transportation were shown two years later when in 1881 the first electric tramway, built by Siemens, was opened in Berlin-Lichterfelde. This had at first a trolley, subsequently a bow contact, and was succeeded by an electrical road vehicle, the "Electromote," the prototype of the later trolleybus. In 1882, the first electric mine locomotive operated in a coal mine in Saxony. Schuckert and Co. in Nuremberg built the first electric rack railway for Wuppertal–Bremen, in 1884. This had a gradient of 185 per thousand, and was from the first fitted with regenerative braking. The first electric underground was commissioned in Budapest in 1886.

**Fig. 1—Locomotive "Adler" and train, as used on the Nuremburg-Fürth railway, 1835 (replica)**

In 1901 came the electric suspension railway Elberfeld–Barmen which is still in operation in its original form. The following year saw the beginning of the Berlin underground system.

Meanwhile an association for the study of electric main-line traction had been formed in 1899, which in 1902–03 carried out very promising trials on the line Marienfelde–Zossen. Here, a Siemens and Halske railcar exceeded the speed of 200km.p.h. Three-phase current was used but this gave rise to difficulties with the necessary double catenary, and therefore was soon abandoned for single-phase current for which a voltage of 15kV, and a frequency of 16⅔ c/s were decided upon. The first electrified network was Magaburg–Dessau–Leipzig whose power stations could be supplied with open-cast brown coal. In Bavaria, where water power was available for the generation of electricity, the main line Murnau to Oberammergau was converted in 1905.

While in the early electric locomotives power was transmitted from the motor to the wheels by means of connecting rods as in a steam engine, the first heavy goods locomotive with individually driven axles was commissioned in 1923 with electrical equipment by Siemens-Schuckert. This company, in 1929, introduced electric welding for fabricating the underframe and bogie frames, the first welded locomotive being the "E44" with 2200kW hourly rating. In 1935 came the experimental use of 50 c/s industrial current on the Hollental railway in the Black Forest. Up to 1945, 1588 route kilometres had been electrified, almost wholly at 15kV, 16⅔ c/s single-phase. Almost no further extensions took place until the beginning of 1950, but in the following six years the German Federal Railway (D.B.) added nearly 600km. The pace was then stepped up to an average of about 400km a year so that at present there are 3755km of electrified routes, an increase of 137 per cent since the war.

Immediately after the war construction continued of fifty-nine locomotives of the designs "E18," "E44," and "E94," dating from 1931–39. Subsequently, in collaboration with the German electrical and locomotive industry, five prototype locomotives were designed. Their layout was basically similar, all having the axle arrangement $B_0$-$B_0$, but both the electrical and the mechanical equipment differed. On the strength of the experiences gained with these engines which were commissioned in 1952–53, the D.B. standardised the specifications for its new locomotive programme.

It was decided to concentrate on four new series. These are the "E10," "E40," "E50," and "E41" series.

The 5000 h.p. "E10" is an 84-tonne, $B_0$-$B_0$ heavy express locomotive with a maximum speed of 150km.p.h. while the "E40" is practically identical with it but has a lower gear ratio, giving it a top speed of 100km.p.h. This locomotive is used mainly for heavy passenger and goods trains in level country. The "E50" is a heavy 100km.p.h. goods locomotive designed particularly for routes with severe gradients. This 128-tonne $C_0$-$C_0$ locomotive, of which forty-eight are now in service, develop 6000 h.p. Finally, the "E41" is a light multi-purpose $B_0$-$B_0$ locomotive weighing 66 tonnes and designed for hauling express and ordinary passenger trains and goods trains at speeds up to 120km.p.h. It may be of interest to note here that the specific weight of these modern designs is of the order of 16 kg per horsepower, as compared with some 80 kg per horsepower in the case of the early electric locomotives. The resulting low weight has made it possible to do without any trailing axles. Much of the saving in weight is due to the rise of fabrication, in particular welded box structures.

In July, the German Federal Railway had 965 electric locomotives, an increase of seventy-two in one year. A further thirty-five are to be supplied in 1960–61, and orders have already been placed for 342 electric locomotives to be delivered in 1962–64.

Mention must also be made of the electric train sets of which the D.B. now possess over 135, and electric railcars of which there are nearly 300. About half of these are battery-operated.

Plans are in hand for extending the electrification to the "North–South" Route, i.e. the connection from Hanau and Gemünden (on the Frankfurt–Bamberg line) northwards through Fulda and Göttingen to Hanover where it branches to Bremen and Bremerhaven on one side and Hamburg on the other. This totals about 850 route kilometres, and if parallel sections and feeder-lines are included, some 1050km of track.

The overall cost is estimated at about DM1000 million, which means about DM200 million per annum if spread over five or six

## CONTINENTAL AFFAIRS *(Continued)*

**Fig. 2 — Diesel-hydraulic locomotive "V-160." This single-engined $B_0$-$B_0$ locomotive develops 1900 h.p. to 2000 h.p. and has a maximum speed of 120 km.p.h.**

years. Next to the Rhine valley lines this route is the most important of the remaining electrification projects as it carries an average of 250 trains per day, with peak traffic of up to 300 trains, and traversing mountainous terrain has reached the limit of its capacity.

Preliminary work such as increasing the loading gauge in the many tunnels has already commenced, but the detailed planning of the main part of the work will have to await a decision as to how the scheme is to be financed.

### Diesel Programme

Diesel-powered traction in Germany dates back to the 1920's, but for about ten years after 1939 nothing was done in this field. The second period of development began in 1950. The decisive factor was the need to reduce the growing steam engine expenditure in fuel and manpower. As in the case of electric locomotives, the policy has been to standardise on a comparatively small number of designs with interchangeable prime movers and hydraulic transmission.

These engines include small locomotives of 120 h.p. and 240 h.p.; the "V-60" shunting engine of 650 h.p.; the "V-100" with 1100 h.p. for mixed service on branch lines; the 1900 h.p. "V-160" for passenger and goods service; the "V-200" with an installed power of 2×1100 h.p. or 2 × 1200 h.p., and designed for medium-heavy passenger and main-line goods services, as well as long-distance trains, and finally the "V-320" of 2 × 1900 h.p. for passenger and goods trains on main lines with heavy traffic. As most of these other lines are to be electrified, it is doubtful whether the locomotive will be required in large numbers; so far only a prototype is said to be under construction.

Diesel railcars include the "VT-95" with 150 h.p.; the "VT-98" with 2×150 h.p. for branch lines; and multiple-coach train-sets "VT-23" ("VT-24") with 2×350 h.p. (2×450 h.p.); "VT-08" ("VT-12") with 1100 h.p.; lastly the seven-coach "VT-11" with 2×1100 h.p. for long-distance and international passenger services including T.E.E. trains.

Since 1955, about 800 "V-60's" have been delivered. This design has three coupled axles which are driven through a torque converter and two hydraulic couplings and a mechanical reversing gearbox. It has been designated an O.R.E. standard.

The "V-160" (Fig. 2) is equipped with a two-stage torque converter and hydraulic clutch, and two-speed mechanical reversing gears. It is intended for passenger or goods train service, being capable of 120km.p.h. in high gear and 75km.p.h. in low gear. Engines of sixteen cylinders, made by three leading German manufacturers, can be used interchangeably in this locomotive, and twelve-cylinder versions of the same engines are fitted in the "V-100." In the first instance, a total of ten "V-160" locomotives has been ordered for trials and these will be supplied during 1960–61.

### Goods Wagons

In severe competitions with other carriers, in particular road transport, the D.B. has rationalised its services, and also endeavours to attract custom by offering a wide range of special goods vehicles, destined for particular classes of goods or intended to facilitate handling of the merchandise. The following are examples showing what has been achieved in this direction.

Mechanical loading and unloading by crane or forklift truck is possible with the "Klmmgks 66" wagon which possesses both a sliding roof and sliding walls. Some 600 are on order.

For transporting bulk goods such as coal, an open, self-discharging truck "Otmm 64" has been put into service. Already 5000 of this design are in use and 1600 more are on order.

Another interesting design is the "Ommi 60" (Fig. 3) equipped with three buckets of 12 cubic metres each which can be electro-hydraulically tipped directly into lorries as illustrated here. The 10·24m-long wagon has a tare weight of 12·1 tonnes and a total useful load capacity of up to 27·5 tonnes.

About ten years ago, the Federal Railway introduced the "BTmms 58" wagon which is capable of carrying five door-to-door containers.

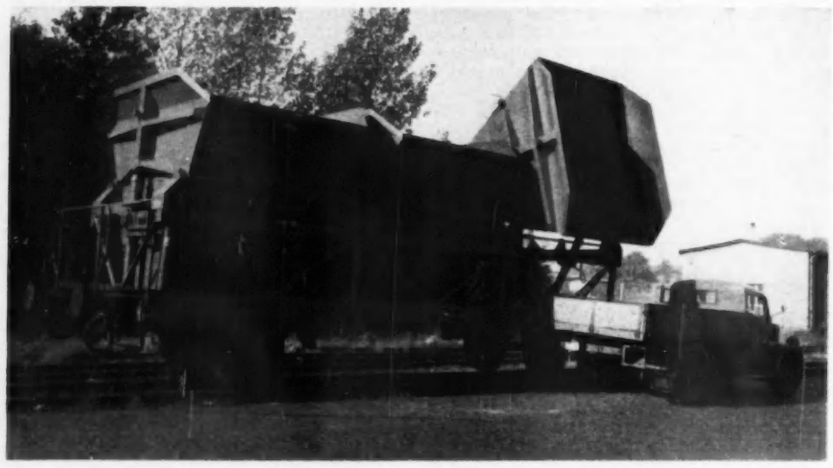


**Fig. 3—Tipper truck with up to 27·5 tonnes carrying capacity. The three bins each hold 12 cubic metres and tip electro-hydraulically at high level, so that they can be discharged over bunker walls near the track or directly into road vehicles**

**Fig. 4—New main station at Munich**

A two-axle wagon, it is designed to utilise fully the permitted axle loading of 20 tonnes, and has the remarkably low tare weight of only 8·1 tonnes.

Generally speaking, the economy of goods transport by rail is being improved by the greater load capacity of modern wagons which now averages about 25 tonnes as compared with 10 to 15 tonnes after World War I, and by increasing the speed of the trains.

Express goods trains, the number of which was raised from nineteen to sixty-six at the end of May, 1960, travel at maximum speeds of 85km to 100km.p.h., while ordinary long-distance goods trains attain 75km.p.h. The introduction of "T.E.E.M." (Trans-Europ Express—Marchandises) international express goods trains is scheduled for 1961–62.

### Buildings

About 45 per cent of all war damage was suffered by railway superstructures and included workshops, sheds, sidings, and other installations, as well as over 450 stations which were 50 to 100 per cent destroyed. In the intervening years some 300 stations have been rebuilt at a cost of DM450 million. For the remaining projects a ten-year plan has been proposed.

Stations which required complete rebuilding included some thirty major ones which each cost from one to several million DM. Nearly forty other large stations have been modernised or substantially altered.

As examples of the modern approach to the planning and design of stations we mention the main line stations of Brunswick and Munich (Fig. 4).

With the opening of Brunswick station on October 2, a major development has been substantially concluded which covers the whole of the Wolfsburg–Brunswick–Salzgitter district. First projected in 1868, but commenced only in 1938, on a rather lavish scale, this re-organisation was stopped towards the end of the war, and continued afterwards at only a greatly reduced rate. Partly this was so because of the changed situation of the district which now found itself situated near the zone frontier and away from the main industrial centres. A department was set up in 1955 at the Hanover office of the Federal Railway with the task of re-shaping these plans and bringing the work to a conclusion.

*Brunswick Main Station.*—A replacement of the old station (built 1845) had already been planned before the war, and because of war damage the matter had become urgent. This station had been constructed as a terminus facing in a southerly direction. The decision proved unfortunate as the resulting complication in handling through-going trains was one of the main causes why the city of Brunswick was by-passed in the following years by competing railway lines, with the result that the city lost its century-old position as a traffic-centre to Hanover.

The new station has four subway-connected platforms which in their central portions are covered over with concrete roofs over a length of 140m. Connection between platforms for mail and luggage trolleys consists of a transverse tunnel reached over ramps at each platform end, as at Heidelberg and Augsburg. The connection between the passenger train siding just outside the station, and the engine sheds on the far side of it, is by an underpassage which has had to be laid out with maximum gradients and minimum radii, but was given full profile suitable for electric locomotives at a later date. The underpassage, which cannot be seen from the signal boxes, has automatic block signals. Our illustration (Fig. 5) shows the main station building which is broadly based on a design competition held in 1956. The entrance hall is a reinforced concrete structure resting on columns. The canopy juts out 7·5m. Sound absorbing ceiling is fastened underneath the hall roof. As may be seen, the entrance is unencumbered by doors. The wall above, up to canopy level, is glazed. Above the entrance hall is the eight-storey office block, 98m long, 29m high but only 7m deep. These measurements were adopted in order to render the building visible from the town centre as the view is somewhat obstructed by a low hill. The foundation stone of the station was laid on March 24, 1959, and the very short completion time could be achieved only by virtue of the fact that the partly-finished building could be heated by the district heating station throughout the winter of 1959–60.

*Bridge Construction.*—Since 1945 the Federal Railways, in addition to current maintenance, expended DM560 million on the rebuilding of war-destroyed bridges, as well as a further DM200 million for replacements. The largest scheme to be undertaken up to the present is the approximate 1000m-long bridge across the Fehmarn Sound which is now under construction and is scheduled to be completed in 1962.

### Operation

Besides the D.B. there exist in the German Federal Republic 216 other railway undertakings which between them operate 5408km of track, mostly single-track. Their function is principally that of feeder lines for the D.B., and in 1959 they carried a total of 130 million passengers and 89,000,000 tonnes of freight. Of these totals, 40 per cent of the passengers and 50 per cent of the freight were transported by non-D.B. railways in North-Rhine Westphalia, the most industrialised and populated part of the country.

However, with over 460,000 employees, the German Federal Railway is the largest transport organisation not only in Germany but in Europe. It operates nearly 31,000km of track, and in the first quarter of 1960, carried over 400 million passengers and 70,000,000 tonnes of goods. Figures covering the material and operational aspects are given in Tables I to III. Receipts in the first half of 1960 amounted to DM4290·2 million, while expenditure totalled DM4391·2 million. Running the DB thus is still involving a deficit which however is steadily being reduced. (In 1957 it was still DM678 million, as against about 200 million for the current year).

In 1959, the Federal Railway required 800,000 tonnes of rails and other rolled steel products, 12,000 tonnes of steel castings, and 63,000 tonnes of grey and temper iron castings. It spent DM611 million on superstructures, DM710 million on rolling stock replacement, expansion and maintenance, DM159 million on electrification and DM680 million on the construction of stations and other work. Consumption of diesel fuel was 120,000 tonnes and a similar amount of oil was used for heating, while electric traction consumed 1560 million kWh.

Table I—*Standard gauge Rolling Stock and consumption of energy of D.B.*

| | July, 1960 | July, 1959 |
|---|---|---|
| Steam locomotives | 7,466 | 8,088 |
| Electric locomotives | 965 | 893 |
| Diesel locomotives | 895 | 619 |
| Small locomotives | 1,180 | 869 |
| Electric railcars (catenary) | 209 | 200 |
| Electric railcars (battery) | 136 | 126 |
| Diesel railcars | 166 | 191 |
| Diesel railcars | 857 | 734 |
| Passenger coaches (including luggage vans) | 23,445 | 24,266 |
| Goods wagons (excluding those privately owned) | 260,240 | 263,561 |
| *Energy Consumption:* | | |
| Steam engines, coal (tonnes) | 565,000 | 598,000 |
| Steam engines, heavy fuel oil (tonnes) | 16,800 | 10,100 |
| Diesel fuel for rail vehicles (tonnes) | 13,800 | 10,450 |
| Electric traction, millions kWh | 160 | 143 |

Table II—*Basic Statistics of German Federal Railways*

Period : January to March, 1960 (in brackets : changes as compared with the same period of 1959)

| | | |
|---|---|---|
| Track length | 30,904km | (− 0·3%) |
| Passenger train kilometres | $90·87 \times 10^6$km | (− 5·1%) |
| Goods train kilometres | $44·14 \times 10^6$km | (+ 8·0%) |
| Gross tonne-kilometres | $50·01 \times 10^9$t.km | (+ 9·0%) |
| Passengers carried | $408·778 \times 10^3$ | (− 0·1%) |
| Passenger kilometres | $9·181 \times 10^9$ | (− 8·0%) |
| Goods, tonnes (excluding service freight) | $72·916 \times 10^6$t | (+14·6%) |
| Tariff tonne-kilometres | $12·945 \times 10^9$t.km | (+16·5%) |
| Goods wagons supplied | $4·640 \times 10^6$ | (+11·1%) |
| Personnel | 461,217 | (− 4·2%) |
| Receipts (DM million) : | | |
| Passenger traffic | 442·541 | (− 6·4%) |
| Luggage traffic | 3·496 | (− 4·8%) |
| Goods traffic | 1,175·720 | (+17·4%) |
| Miscellaneous | 108·000 | (+ 9·1%) |
| Total receipts | 1,729·755 | (+ 9·7%) |

Table III—*D.B. Services*

Period : January to July 1960 (in brackets( for use same period of 1959)

| | Passenger trains (excluding S-Bahn)* | S-Bahn* Hamburg | Goods and service trains | Total |
|---|---|---|---|---|
| Train-kilometres, in 1000's | 214,901 (223,876) | 4,224 (4110) | 106,455 (100,709) | 325,580 (328,695) |
| Axle-kilometres, in millions | 4246·8 (4317·2) | 99·8 (100·1) | 7882·3 (7186·5) | 12,228·9 (11,603·8) |
| Net tonne-kilometre of goods wagons in all trains (millions) | | | 36,262·6 (32,253·8) | |
| Locomotive and railcar kilometres, in 1000's | | | 423,176 (427,830) | |
| Average number of axles | 19·6 (19·3) | 23·6 (24·4) | 74·0 (71·4) | — |
| Average net load of long-distance goods train (tonnes) | | | 476·1 (460·3) | |
| Provision of goods wagons : | | | | |
| Covered | | | 5,023,559 (4,793,331) | |
| Open | | | 4,349,314 (3,981,475) | |
| Others | | | 1,826,794 (1,759,367) | |
| Total | | | 11,199,667 (10,534,173) | |
| Number of working days | | | 170·04 (170·67) | |
| Turn-round time (days) | | | 4·59 (4·56) | |
| Passenger traffic (millions)‡ | | | 778 (809) | |
| Passenger-kilometres (millions)‡ | | | 22,798·7 (23,170·9) | |
| Goods carried (thousands of tonnes) | | | 182,374 (167,317) | |
| Of which public and military transport | | | 166,321 (151,423) | |

* Hamburg suburban lines.
† S-Bahn passengers totalled about 10 per cent.
‡ S-Bahn passengers totalled about 3·6 per cent.

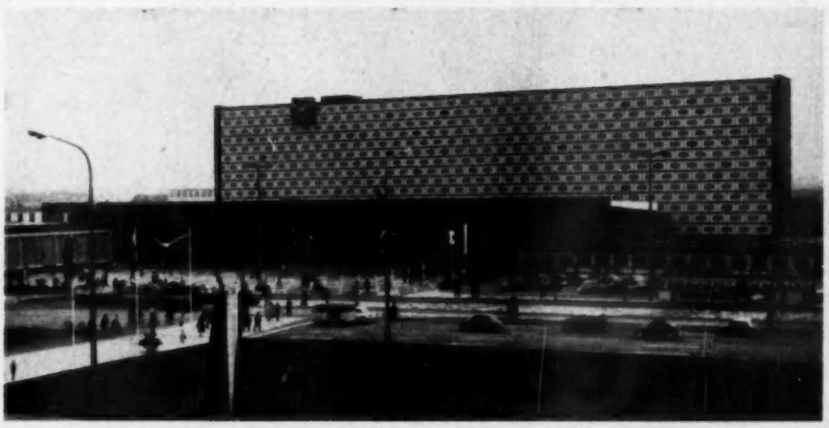


Fig. 5—Brunswick main station, commissioned October, 1960

# THE AMERICAN SCENE

*by Our American Editor*

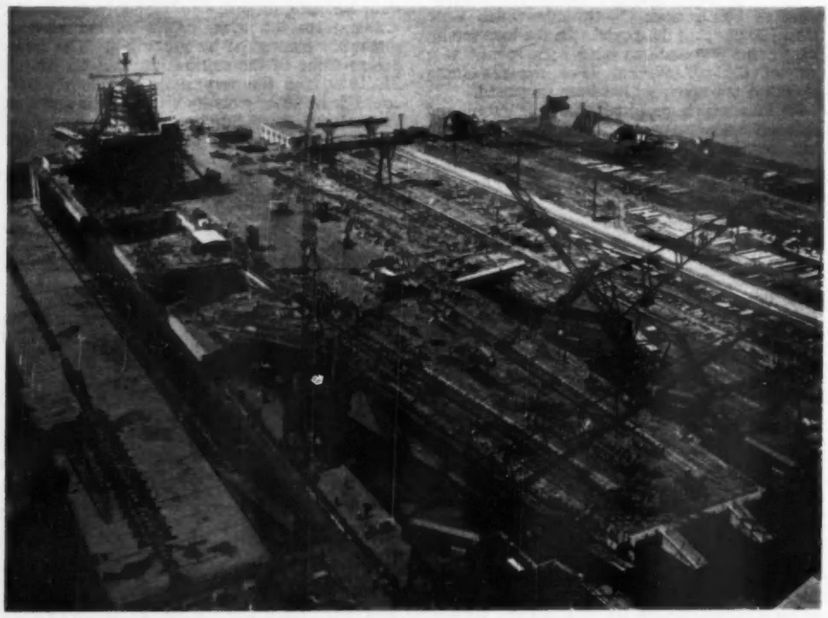
## Launch of U.S.S. " Enterprise "

The first nuclear attack aircraft carrier of the U.S. Navy was launched recently at the Newport News yard of the Newport News Shipbuilding and Dry Dock Company in Virginia. In naval history, the attack aircraft carrier has extended air power on the seas to revolutionise modern naval warfare. This weapon has had an extraordinary growth and development since the keel of the first vessel built as an aircraft carrier was laid at Newport News on September 26, 1931. As heavier aircraft with higher speeds and longer ranges have been developed to extend their capabilities, larger and better equipped carriers have been constructed to serve as their floating landing fields anywhere on the high seas. The carrier " Enterprise " incorporates the latest of these developments and is also to be driven by nuclear energy. With her length of 1101ft and displacement of 85,350 tons, the " Enterprise " is not only the largest carrier ever built, but also the world's largest ship. When she joins the Fleet in the autumn of 1961, she will give the U.S. Navy the advantage of having the only nuclear-powered aircraft carrier in the world. When she is commissioned as CVA(N)65, it is anticipated that she will be the first naval combatant surface vessel to operate on nuclear power, not only in the U.S. Fleets, but in any nation's navy. The first vessel ever designed with more than two nuclear reactors, the " Enterprise " will have eight pressurised water reactors arranged in four dual systems to drive her four propellers. In combination, they make up the world's most powerful atomic power plant, afloat or ashore. With this plant producing horsepower rated at 280,000 s.h.p. and driving her at speeds of 33 to 35 knots, the " Enterprise " will be capable of operating for several years without refuelling.

The vessel's propulsion plant has been benefiting from the " A1W " land-based prototype installation at the Idaho reactor testing station. This facility is a full-scale operating prototype of the " Enterprise " No. 3 machinery plant : two reactors and a turbine driving a slow-speed generator. Two full-scale reactors were felt to be necessary for the prototype because the dynamics and control characteristics of two reactors connected to a single shaft were an unexplored area. Advantage was taken of the situation to develop two different core designs and to try out variants in nuclear components—for example, one of the reactors has all structural parts in contact with primary water made of carbon steel instead of types 304 or 347 stainless steel to test the feasibility of using this less expensive but more corrosible material.

Besides her nuclear plant, the " Enterprise " will have many advances in carrier design and development since the first U.S.S. " Ranger " (CV-4), was completed by Newport News in 1934. Her angled flight deck allows for the simultaneous launching and landing of 'planes. The four powerful catapults of the latest design will fling her heavy jet aircraft into the air at their fast flying speeds in a few seconds. In a matter of minutes, her four giant deck-edge elevators will carry her aircraft from the hangar deck to the flight deck for launching. Two and a half years in the building to her launching date, the " Enterprise " will require another year for outfitting before she is commissioned in the autumn of 1961. The contract was awarded in November, 1957, and her keel was laid on February 4, 1958, in Graving Dock No. 11, which had to be lengthened to 1100ft to accommodate her.

Traditionally, a ship is launched by sliding down the shipway upon which she is built into the water. The " Enterprise," however, became waterborne for the first time in her building dock and thus was " launched by flotation." To signal the launching of the " Enterprise " more dramatically for the guests and spectators, the series of lights spelling out her name on the bow were lighted one by one by the floating of the vessel. The lights which spelled out her name were being activated electrically through relays attached to the keel blocks.



**Erection of the elevators and the tower and mast of the U.S.S. " Enterprise " in the No. 11 graving dock at Newport News**

**The nuclear attack aircraft carrier " Enterprise " afloat in the James River after floating of the vessel in a graving dock**

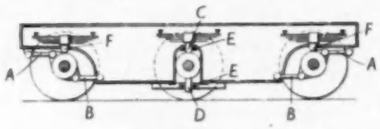
# BRITISH PATENT SPECIFICATIONS

*The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each*

## RAILWAY VEHICLES

**855,598.** January 10, 1957.—RAIL VEHICLES, Krauss-Maffei Aktiengesellschaft, Munchen-Allach, Germany. (*Inventor : Thomas Wirth.*)

This invention relates particularly to rail vehicle bogies, fitted with three or more wheel sets. The axlebox of each outer wheel set is connected to the vehicle frame by an axle guide rod, the connections of which substantially eliminate displacement of the wheel sets both longitudinally and laterally. The axleboxes of the intermediate wheel set are mounted in vertical guides which also provide for displacement both longitudinally and laterally. In the embodiment illustrated the side frames are located outside the




No. 855,598

wheels and the wheels of the two outer wheel sets have axleboxes disposed within recesses in the side frames. Each outer axlebox is connected to the side frame by a pair of guide rods *A*, *B*. The connections of the guide rods to the axlebox are diametrically opposed and are so located that the two rods, both of which extend horizontally, are at different heights above the track. The upper rod *A* is connected to the bogie side frame, by a bracket, and the lower rod *B*, extending towards the intermediate wheel set, is connected direct to the side frame. Each guide rod is connected to the axlebox and side frame by "Silentbloc" elements. The axleboxes of the intermediate wheel set are vertically guided between ways and have opposed vertical pins *C*, *D*, of circular or polygonal shape guided in a sleeves *E* mounted in rubber bushes. The upper bush is secured to the side frame, while the lower bush is carried by a hornplate stay secured to the base of the side frame. The shackle of each outer spring assembly carries a depending pin *F* which engages the associated axlebox, while the shackle of the intermediate spring assembly rests on the associated upper pin *C*. The guide arrangements for the intermediate axleboxes, in addition to providing for vertical displacement within their recess, also enable the boxes to move horizontally both longitudinally and transversely of the bogie. Another embodiment shows the construction of a bogie side frame disposed inside of the wheels.—*December* 7, 1960.

## ELECTRICAL ENGINEERING

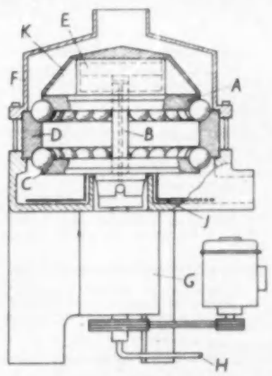
**856,353.** March 6, 1958.—RELAY CONSTRUCTION, Allmänna Svenska Elektriska Aktiebolaget, Väasteras, Sweden.

Known means for supporting the relay armature and contact mover on the frame of an electromagnetic relay have the disadvantages that they do not give a fully satisfactory guidance of the armature, and that the mechanical wear of the supporting means and of the contact mover are considerable. The arrangement according to this invention has the advantages of being very simple, of giving a reliable guidance to the relay armature and of reducing the mechanical wear of the contact mover to a minimum. It consists of a thin foil of electrically insulating plastic material, which at one end is fastened to the outside of the relay frame and at its other end to the relay armature, to which the contact mover is also attached. Due to its great flexibility and softness it is easy and cheap to manufacture such plastic material in any desired form. The flexible part of the plastic strip can be made rather short, so that the armature moves as if it were arranged on hinges, but without the friction at the hinges. Nevertheless a long movement of the armature can be obtained. By giving the plastic strip a suitable form, the armature and the contact mover can be made to hit the plastic material at the end positions of their movement, so that a noiseless operation of the relay is obtained. Since metallic parts do not slide upon each other, a minimum of wear is obtained. The foil may be of a polyamide plastic or tetrafluoroethylene plastic. In order to increase its flexibility it can be provided with short, transverse slits. In order to obtain still more secure guidance of the armature, one end of the foil can be divided into three flaps, the two outer flaps being folded round the outer end of the relay frame and attached to its inner side, while the middle flap is fastened between the armature and contact mover, as before.—*December* 14, 1960.

## GRINDING MILLS

**855,044.** October 31, 1958.—BALL-BEARING GRINDING MILLS, George Fischer Aktiengesellschaft, Schaffhausen, Switzerland.

The grinding mill shown has an inner ball race *A*



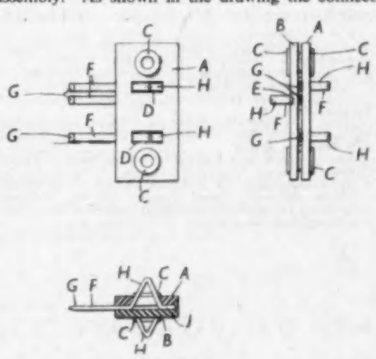

No. 855,044

driven by a shaft *B* which is axially displaceable with respect thereto. A second ball race *C* is also fixed to the shaft. A ring *D* is interposed between the races and at each end has peripheral grooves, the walls of which form a grinding surface for the balls retained by the races. The cylinder of a pneumatic pressure device has an associated piston *E* fixed on the driving shaft. The upper part *F* of the mill housing has an aperture through which material to be ground is fed in. A spiral shaped lower part of the housing contains a drive unit *G*, a compressed air supply pipe *H* and a centrifuging ring *J*. The material to be ground passes onto the cover *K* and is fed to the first grinding set comprising the inner ball race *A*, the grinding balls and the surface of the ring *D*. It is then fed through the second grinding set. The ground material is then conveyed outwardly by the centrifuging ring *J* through an aperture in the lower part of the housing. The pneumatic pressure in the cylinder forces the races towards each other and the balls against the grinding surfaces. The degree of pressure necessary depends on the material to be ground and on the desired fineness. The grinding pressure and the grinding fineness can also be influenced by an appropriate choice of the driving speed. Alternative designs of the grinding mill are also described in the specification.—*November* 30, 1960.

## CIRCUIT COMPONENTS

**855,852.** July 30, 1958.—ELECTRICAL PLUG CONNECTORS, Carr Fastener Company, Ltd., Pinfold Lane, Stapleford, Nottinghamshire. (*Inventor : Anthony Brasher Clewes.*)

The plug connector described in this specification is particularly suitable for use with sub-miniature components such as transistors, which have to be connected to a panel or other part of an electrical assembly. As shown in the drawing the connector

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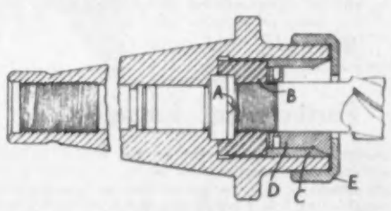
comprises a pair of relatively thin plates *A*, *B* of insulating material of rectangular shape and secured in superposed relation by rivets *C*. The plate *A* is formed with two slots or apertures *D* and the plate *B* with a slot or aperture *E*. Three contacts *F* are provided, each comprising a strip of metal including an electrical plug blade *G*, a medial portion bent to form a "U" or "V" shaped portion *H* projecting substantially at right angles to the plug blade *G* and a tab portion *J* extending in an opposite direction to the plug blade *G*. In assembling the connector the contact members *F* are positioned on the inner faces of the plate so that the "U" or "V" shaped projections *H* of two contacts extend through the slots in the plate *A* and the projection *H* of the third contact extends through the slot in the plate *B*. When the plates are assembled in superposed relation the tab portions *J* extending from one arm of the "V" or "U" shaped portions *H* and the portions of the plug blades *G* extending from the other arm will be sandwiched between the inner faces of the plates. The plates are then secured by the rivets *G*. The plug blades *G* project outwardly of the edges of the plates for insertion into a co-operating socket member or into an aperture in a panel or the like of insulating material carrying electrical conductors. The "U" or "V" shaped projecting portions *H* of the contacts serve as a tag to which a component or the lead wire of a component may be attached as by soldering. The panel may have an electrical circuit diagram provided or otherwise marked on one face, parts of the diagram extending to the plug-receiving aperture of the panel such that when the plug is inserted into the aperture the component attached to the plug will be connected to that part of the circuit diagram.—*December* 7, 1960.

## TOOLS

**856,264.** September 7, 1959.—TOOL HOLDERS AND CHUCKS, Samuel Osborn and Co., Ltd., Clyde Steel Works, Wicker, Sheffield, 3. (*Inventors : Roderick Fred Hughes and Bernard Smith.*)

This invention relates to tool holders or chucks for use on machine tools. It is used with threaded shank milling cutters, drills or other tools, the gripping action of the chuck being provided by a split collet, a conical surface on the collet contracting it into the shank. As shown in the drawings, the hollow cylindrical body of the chuck has, at the inner end, a limit stop formed on the head *A* of a centre in the bore of the tapered shank. The head *A* engages an annular shoulder at the inner end of the body and has two opposed flats to prevent its rotation. An internally threaded collar *B* having two projecting

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lugs is slidable in the body and the lugs engage over the flats on the head of the centre. A sleeve *C*, also a sliding fit in the body, abuts the outer end face of the collar. The outer end of the sleeve has an internally coned surface. The sleeve surrounds a tool shank receiving collet *D* having three partially separated segments formed by slits which extend for the greater part of the length. The outer end of the collet is enlarged to match the sleeve. A shallow annular groove is cut in the collet at the junction of its cylindrical and conical surfaces preventing it from binding in the sleeve. The tool-receiving end of the chuck is completed by a cap *E* screwed on to the body. The shank of the drill or cutter is inserted into the chuck and screwed into the threaded collar *B* until it abuts the stop. Further rotation of the shank will tend to draw the collar out of the body and this axial movement is transmitted to the sleeve *C*, which in turn will, through the conical surfaces, exert a radial force inwardly on the segments of the collet forcing them to grip the shank of the tool. The lugs on the collar and the flats on the head are large to ensure adequate strength and gripping force. It is stated to have been found that the use of a moving sleeve instead of a moving collet results in obtaining a better grip on the shank of the tool as there is substantially no longitudinal movement of the collet in the chuck body.—*December* 14, 1960.

### HYDRAULIC EQUIPMENT

**856,478.** July 22, 1959.—HYDRAULICALLY-DRIVEN MOTOR WITH FRICTION BRAKE, Kamper-Motoren G.m.b.H., Berlin-Marienfelde, Grossberenstrasse 174, Germany.

It is the object of the invention to provide a simple construction of hydraulically-driven motor and hydraulically-controlled friction brake by building the motor and brake in the same housing. The braking force is applied by plate springs, and the brake released by the oil pressure in the motor. The initial tension in the plate springs is adjustable and thus also the force necessary for the release of the brake. The non-rotating part of the brake is preferably constructed as a sleeve having an internal conical surface. This sleeve is mounted concentrically with the piston drum of the motor and when axially displaced acts directly upon that part of the motor which generates the torque. A double piston, against which the control oil operates to release the brake, gives a considerable increase of the lifting force and increased brake power. In a drawing accompanying the specification one embodiment of the invention is diagrammatically illustrated by way of example.—*December* 14, 1960.

### MOULDS AND DIES

**854,636.** February 25, 1957.—MOULDS, DIES AND FORMING TOOLS, Leicester, Lovell and Co., Ltd., North Baddesley, Southampton, Hampshire. (*Inventor : William Haydn Thomas John.*)

This invention relates to an improved method of making moulds, dies and forming tools. Moulds and tools made by casting epoxide resin compositions, containing suitable curing agents (hardeners) and fillers, have many properties, including dimensional accuracy, surface finish, hardness and mechanical strength. It has been found, however, that these cast epoxide tools show significant wear after making a fraction of the number of pressings which a steel press tool would give. Improvement can be obtained by producing cast plastic tools having thin, hard, metallic skins on their working surfaces. The invention provides a means of combining the higher strength and wear resistance of metallic substances with the ease of forming and dimensional accuracy of cast plastic compositions. This is achieved by forming a thin skin over the surface of a pattern mould by deposition of a metal or of a metallic alloy and casting an epoxide resin composition in the metallised mould. The skin of metal adheres to the surface of the casting. The metal deposited is chosen to confer the required wear-resistance of the mould and the thickness of the deposit must be controlled to ensure that the required life is obtained without risk of distortion of the surface arising from too great a thickness of deposited metal. It is stated that a draw-die made in the way described and having a surface of sprayed nickel-chrome-molybdenum alloy backed by the slate-filled cast epoxide resin, gave 27,000 pressings without any significant wear.—*November* 23, 1960.

## Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

#### ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

*Today, Dec.* 30.—COVENTRY AND DISTRICT BRANCH : E.M.E.B. Sports and Social Club, Merrick Lodge, Sandy Lane, Coventry, "Development of Electrical Equipment for Machine Tools," J. N. Leah, 7.30 p.m.

#### BRITISH INSTITUTION OF RADIO ENGINEERS

*Wed., Jan.* 4.—RADAR GROUP : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Automatic Techniques in Civil Air Line Communications Systems," W. E. Brunt, 6.30 p.m.

#### COMBUSTION ENGINEERING ASSOCIATION

*Tues., Jan.* 10.—NORTHERN REGION : Grand Hall, Sheffield, Discussion on "The Problem of Grit Emission," 2.30 p.m.

#### ILLUMINATING ENGINEERING SOCIETY

*Mon., Jan.* 2.—BIRMINGHAM CENTRE : Bennett Hall, Y.M.C.A., Snow Hill, Birmingham, Display of Lighting Fittings, 6 p.m.
*Thurs., Jan.* 5.—NOTTINGHAM CENTRE : Electricity Centre, Carrington Street, Nottingham, "Light Effect on Dyes," W. L. Lead, 6 p.m.
*Mon., Jan.* 9.—SHEFFIELD CENTRE : Grand Hotel, Sheffield, "Recent Developments on the Continent in Exterior Lighting," A. G. Penny, 6.30 p.m.

#### INSTITUTE OF METALS

*Tues., Jan.* 3.—OXFORD LOCAL SECTION : Cadena Café, Cornmarket Street, Oxford, "Meteorites," H. J. Axon, 7.15 p.m.
*Wed., Jan.* 4.—LEEDS METALLURGICAL SOCIETY : Institute of Technology, Bradford, "Some Recent Developments in the Welding of Metals," E. N. Gregory, 6.30 p.m.
*Thurs., Jan.* 5.—LONDON LOCAL SECTION : 17, Belgrave Square, London, S.W.1, "Metallurgy in Electronics," J. E. Hughes, 6.30 p.m. ★ BIRMINGHAM LOCAL SECTION : College of Technology, Gosta Green, Birmingham, "Vacuum Technology," T. Thorley, 6.30 p.m.

#### INSTITUTE OF PETROLEUM

*Wed., Jan.* 4.—61, New Cavendish Street, London, W.1, "Pre-Flame Reactions in Diesel Engines, Part V—A Study of Temperature, Pressure and Ignition Delay," F. H. Garner, Frank Morton and J. B. Saunby, 5.30 p.m.

#### INSTITUTE OF PLANT ENGINEERS

*Tues., Jan.* 3.—PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, "Future Railway Development in Peterborough and District," 7.30 p.m.
*Wed., Jan.* 4.—EDINBURGH BRANCH : 25, Charlotte Square, Edinburgh, "Heating," A. A. Kidd, 7 p.m. ★ LEICESTER BRANCH : Midland Hotel, Leicester, "The River Dove Water Scheme," H. Wallhouse 7.30 p.m. ★ SOUTHERN BRANCH : Polygon Hotel Southampton, Members' Discussion, "My Job," 7.30 p.m.

#### INSTITUTE OF REFRIGERATION

*Thurs., Jan.* 5.—Institute of Marine Engineers, Memoria Building, 76, Mark Lane, London, E.C.3, "The Use of Two Stage Freezing Procedures for Eviscerated Chicken," R. Gane and D. H. Shrimpton, 5.30 p.m.

#### INSTITUTE OF ROAD TRANSPORT ENGINEERS

*Tues., Jan.* 3.—WESTERN CENTRE : Royal Hotel, Bristol, "Air Brakes for Commercial Road Vehicles," W. A. Kirk, 7 p.m.
*Thurs., Jan.* 5.—SOUTH WESTERN GROUP : Exeter City Fire Brigade, Exeter, "Servicing of Electrical Equipment," J. H. Stoneman, 7.30 p.m.

#### INSTITUTION OF ELECTRICAL ENGINEERS

*Mon., Jan.* 2.—SOUTH MIDLAND CENTRE : James Watt Memorial Institute, Birmingham, Discussion on "Broadening University Courses," opened by H. E. M. Barlow, 6.30 p.m.
*Tues., Jan.* 3.—NORTH MIDLAND CENTRE : Leeds and County Conservative Club, South Parade, Leeds, 1, "Water-Turbine-Driven Induction Motors," C. L. C. Allan, 6.30 p.m.
*Wed., Jan.* 4.—TEES-SIDE SUB-CENTRE : Cleveland Scientific and Technical Institution, Middlesbrough, "The Fylingdales Early Warning Station," D. R. Evans, 6.30 p.m. ★ SHEFFIELD SUB-CENTRE : City Hall, Sheffield, "Colour Television," R. Feinberg, 3 p.m. ★ SOUTHERN CENTRE : The University, Southampton, "The Planning and Economics of Telecommunication Plant," C. J. Stubbington, 7 p.m.
*Thurs., Jan.* 5.—ORDINARY MEETING : Savoy Place, London, W.C.2, Third Hunter Memorial Lecture, "The Application of Electronics to the Electricity Supply Industry," J. S. Forrest, 5.30 p.m.

#### INSTITUTION OF MECHANICAL ENGINEERS

*Tues., Jan.* 3.—COVENTRY A.D. CENTRE : Grosvenor Room, Hotel Leofric, Coventry, "Recent Knowledge of Combustion," J. S. Clarke, 7.15 p.m.
*Thurs., Jan.* 5.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "The Reliability of Mechanical Engineering Parts of Data Processing Equipment," 6 p.m. ★ EASTERN BRANCH : Hoffman's Social Hall, Chelmsford, "The Investigation of Radio Sources at Jodrell Bank," H. P. Palmer, 7.30 p.m. ★ EAST MIDLANDS BRANCH : Room 104, College of Technology and Commerce, Leicester, "The Vibration of Vertical Milling Machines under Test and Working Conditions," S. A. Tobias, 7.15 p.m. ★ WESTERN A.D. CENTRE : Royal Hotel, Bristol, Informal meeting, 6.45 p.m.
*Fri., Jan.* 6.—NORTH EASTERN BRANCH : Neville Hall, Westgate Road, Newcastle upon Tyne, Chairman's Address, 6 p.m.

#### INSTITUTION OF PRODUCTION ENGINEERS

*Mon., Jan.* 9.—SHEFFIELD GRADUATE SECTION : B.I.S.R.A. Lecture Theatre, Hoyle Street, Sheffield, 3, "Grinding Wheels and their Application," C. Perrett, 6.30 p.m.

#### INSTITUTION OF PUBLIC HEALTH ENGINEERS

*Mon., Jan.* 2.—Caxton Hall, London, S.W.1, Discussion on "The Use of Light Alloys on Sewage and Water Works," introduced by H. Thatcher, 6 p.m.

#### INSTITUTION OF STRUCTURAL ENGINEERS

*Tues., Jan.* 3.—NORTHERN COUNTIES STUDENTS' AND GRADUATES' BRANCH : Cleveland Scientific and Technical Institution, Middlesbrough, "Design of Welded Plate Girders," O. A. Kerensky, 6.30 p.m. ★ NORTHERN IRELAND BRANCH : Civil Engineering Department, David Keir Building, Queen's University, Belfast, Lecture and Film on "Piling," C. H. Bunclark, 6.30 p.m.
*Wed., Jan.* 4.—NORTHERN COUNTIES BRANCH : Neville Hall, Newcastle upon Tyne, "Value for Money in Building," E. S. Benson, 6.30 p.m.
*Fri., Jan.* 6.—GRADUATES' AND STUDENTS' SECTION : Engineering Centre, Stephenson Place, Birmingham, "Precast Concrete Frame Construction," B. E. Griffin, 6.30 p.m. ★ WESTERN COUNTIES BRANCH : Small Lecture Theatre, University Engineering Laboratories, University Walk, Bristol, 8, "Lift-Slab Design and Construction," F. R. Benson, 6 p.m.

#### INSTITUTION OF WELDING

*Thurs., Jan.* 5.—54, Princes Gate, Exhibition Road, London, S.W.7, Second Christmas Lecture to Young Children, "Sticking Things Together," J. G. Ball, 11 a.m.

#### JUNIOR INSTITUTION OF ENGINEERS

*Today, Dec.* 30.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Films, "Yorkshire Transformer," "One for the Road," "Giant Load," and "Power Plant by Road to Site," 7 p.m.
*Wed., Jan.* 4.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, "Engineering in Chemical Works," E. R. Brazier, 7 p.m.

#### NEWCOMEN SOCIETY

*Wed., Jan.* 4.—Science Museum, London, S.W.7, "Joshua Gilpin, an American Manufacturer in England and Wales : Part II, 1811-14," Harold B. Hancock and Norman B. Wilkinson, 5.30 p.m.

#### PLASTICS INSTITUTE

*Mon., Jan.* 2.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Young People's Lecture, "Plastics and Textiles," H. A. Thomas, 2.30 p.m.

#### REINFORCED CONCRETE ASSOCIATION

*Tues., Jan.* 3.—MIDLAND COUNTIES BRANCH : Birmingham and Midland Institute, Paradise Street, Birmingham, "Reinforced Concrete Construction in the Coal Industry," C. A. C. Davies, 6 p.m.
*Fri., Jan.* 6.—WEST OF ENGLAND BRANCH : University Engineering Laboratories, University Walk, Bristol, 8, Joint meeting with the Western Counties Branch of the Institution of Structural Engineers, "Lift Slab Design and Construction," F. R. Benson, 6 p.m.

#### ROYAL AERONAUTICAL SOCIETY

*Tues., Jan.* 3.—ASTRONAUTICS AND GUIDED FLIGHT SECTION : Lecture Theatre, 4, Hamilton Place, London, W.1, "Planning of Missile Acceptance Trials," J. F. W. Mercer and A. R. Cawthorne, 6 p.m.
*Thurs., Jan.* 5.—Young People's Lecture : Lecture Theatre, 4, Hamilton Place, London, W.1, "Gyroscope and Pendulum —the Modern Travel Agents," R. J. Lees, 3 p.m.

#### ROYAL INSTITUTION

*Thurs. and Sat., Dec.* 29 *and* 31.—21, Albemarle Street, London, W.1, Course of six lectures, "Seeing the Very Small," No. 1—"The Microscopical World," and No. 2—"The Eye and the Simple Lens," V. E. Cosslett, 3 p.m.
*Tues., Jan.* 3.—21, Albemarle Street, London, W.1, "Seeing the Very Small—No. 3. The Compound Microscope and its Limitations," V. E. Cosslett, 3 p.m.
*Thurs., Jan.* 5.—21, Albemarle Street, London, W.1, "Seeing the Very Small—No. 4. The Electron Microscope," V. E. Cosslett, 3 p.m.

#### ROYAL INSTITUTION OF CHARTERED SURVEYORS

*Mon., Jan.* 2.—ORDINARY GENERAL MEETING : 12, Great George Street, Parliament Square, London, S.W.1, "Fire Precautions in Buildings," F. W. Delve, 5.45 p.m.

#### ROYAL INSTITUTION OF NAVAL ARCHITECTS

*Thurs., Jan.*—10, Upper Belgrave Street, London, S.W.1, Third Amos Ayre Lecture, A. Hunter, 4.45 p.m.

#### SOCIETY OF CHEMICAL INDUSTRY

*Wed., Jan.* 4.—CORROSION GROUP : Cathodic Protection Panel : 14, Belgrave Square, London, S.W.1, Discussion on "Galvanic Anodes," 6 p.m.

#### SOCIETY OF INSTRUMENT TECHNOLOGY

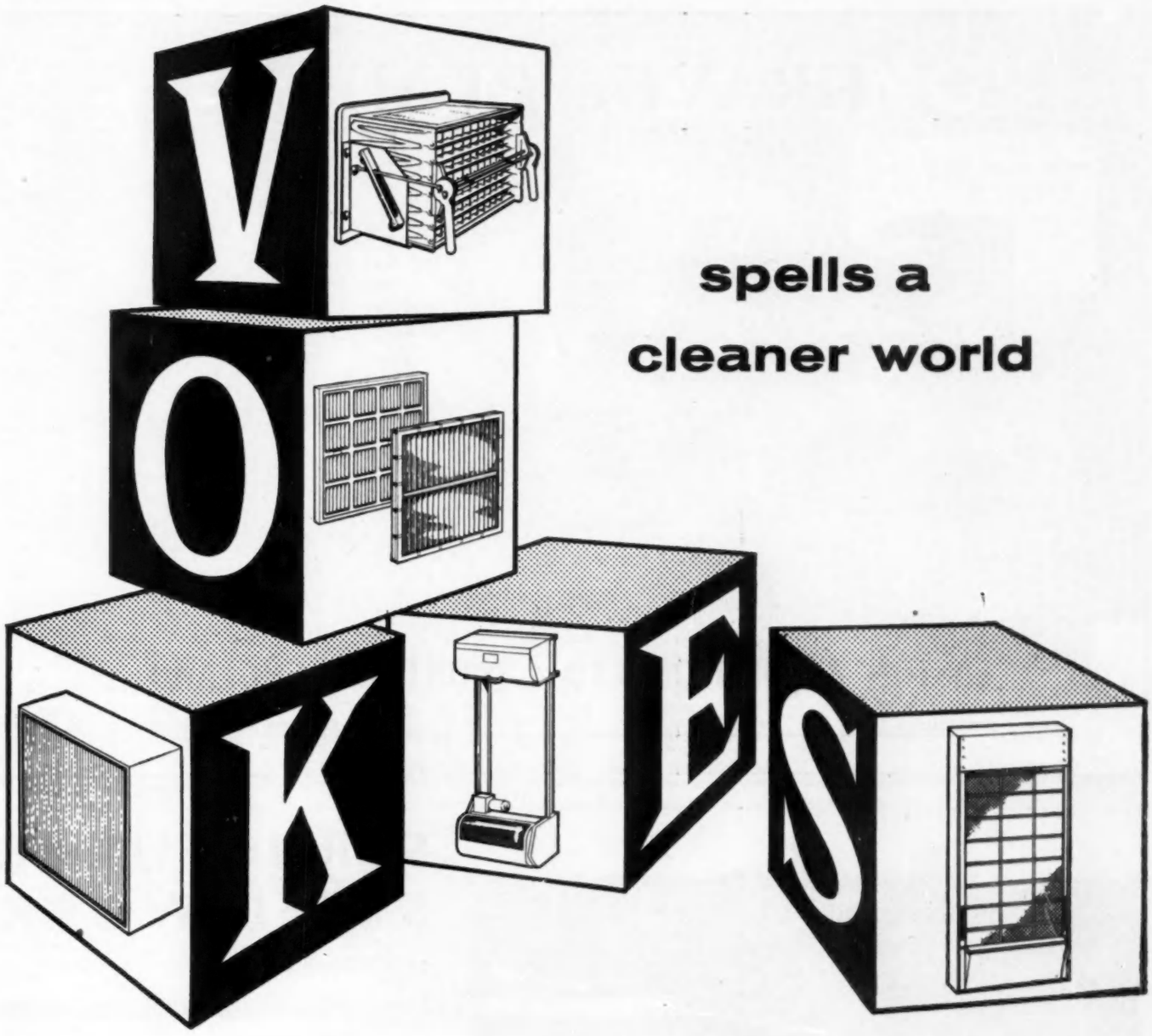
*Fri., Jan.* 6.—FAWLEY SECTION : Administration Building, Esso Refinery, Fawley, "Electronics and Instrumentation in the Glass Industry," J. R. Beattie, 5.30 p.m.

## Advanced Engineering Courses

**The Principles of Radiation Protection.** THE REACTOR SCHOOL, ATOMIC ENERGY RESEARCH ESTABLISHMENT, Harwell, Berkshire. The fourth advanced radiation protection course comprises lectures, practical work, demonstrations and visits, and is intended for graduates or persons of graduate standard either entering or already working in the field of radiological health and safety. The course will cover a wide field of fundamental background knowledge and will deal with principles rather than with particular techniques. A high academic standard is set, but since few academic courses cover all the necessary subjects, the course of lectures will begin with first principles, and will not require previous specialised knowledge.
The theoretical part of the course consists of about 110 lectures under three main headings, "Basic Scientific Principles," "Principles of Radiation Protection" and "General Topics."
The course runs from April 19 to July 18, 1961. Fee £250 exclusive of accommodation.

**Production Planning and Control.** THE UNIVERSITY OF BIRMINGHAM, Institute for Engineering Production, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. The primary aim of the course is to discuss methods of production planning and control and the application of systematic analysis to these functions with a view to the improvement of organisational and production efficiency. The course is intended for industrial executives, senior production engineers and controllers, O. and M. personnel and other specialists in related fields. The course runs from Monday, February 6, until Friday, February 17, 1961. The inclusive charge for the two-week residential course is sixty guineas.

END OF VOLUME 210

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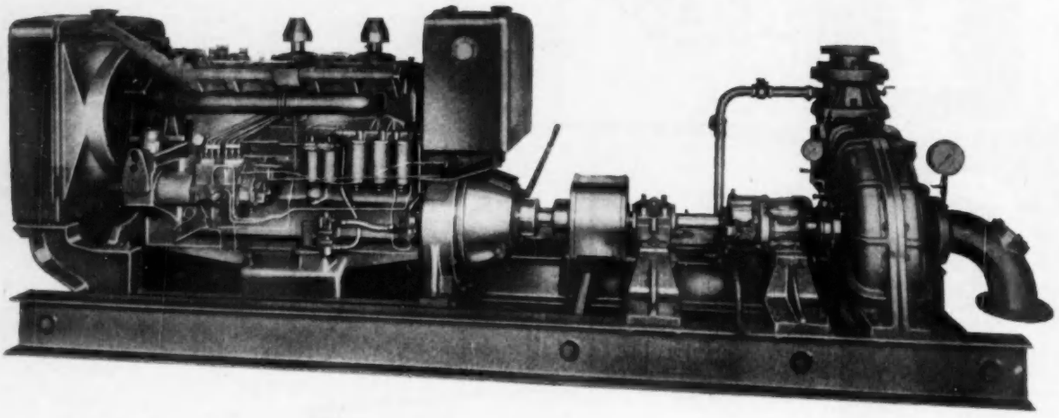

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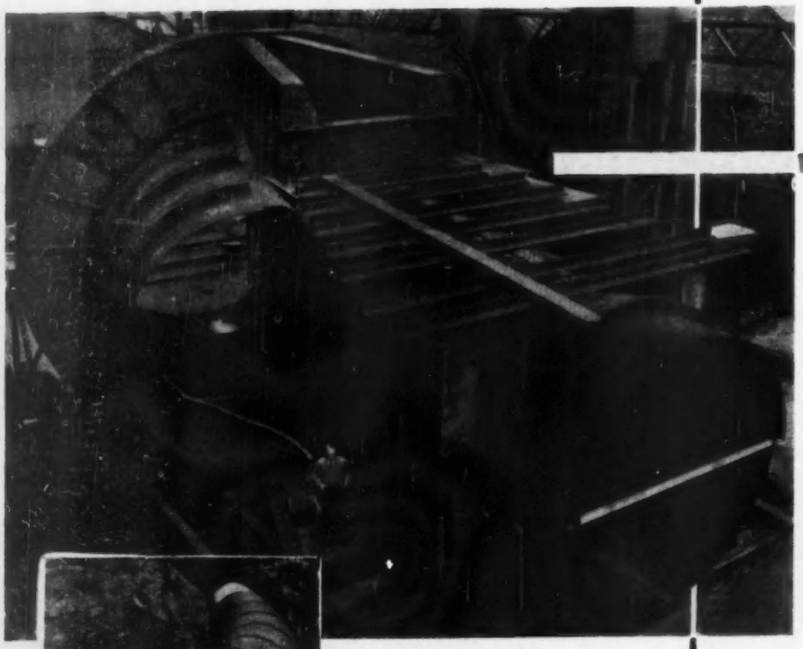

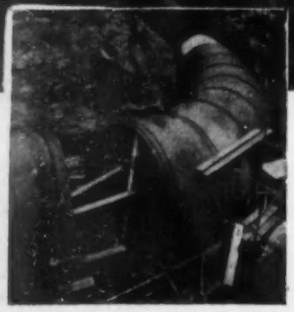

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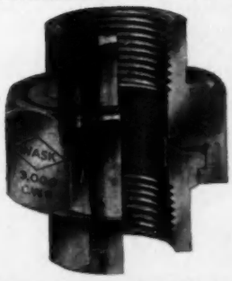

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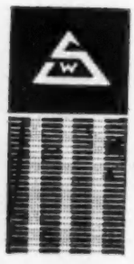

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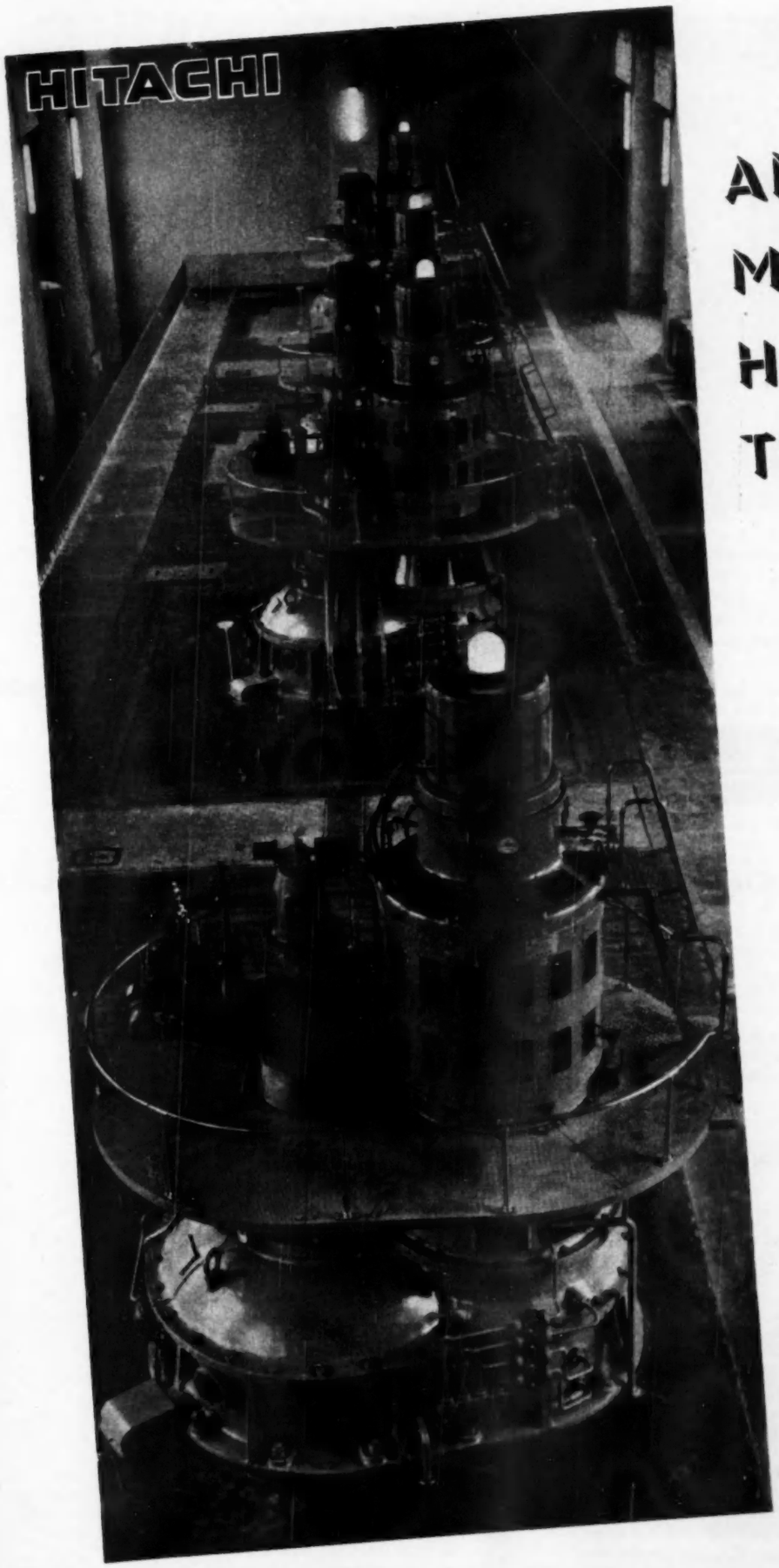


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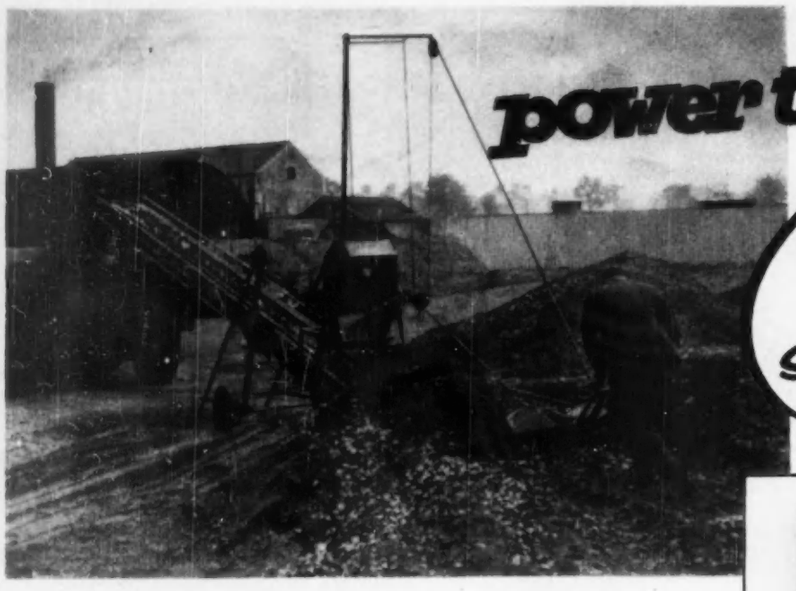

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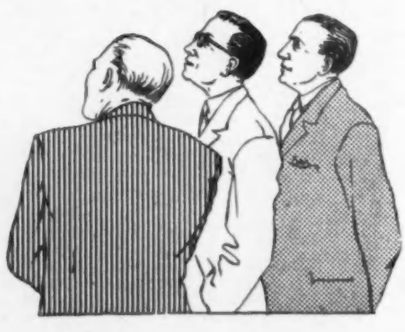

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# CENTRAL ELECTRICITY GENERATING BOARD

## TARIFF FOR BULK SUPPLIES TO AREA BOARDS

fixed by the Central Electricity Generating Board (the Generating Board) pursuant to section 37 (1) of the Electricity Act, 1947, for the year ending 31st March, 1962

### NORMAL KILOWATT CHARGE

£7.7.0d. (seven pounds seven shillings) for each kilowatt of the number ascertained by multiplying by 26,350,000

the maximum number of kilowatts determined by deducting from the **half-hour kilowatt demand** supplied to the Area Board the **half-hour kilowatt demand** of the **special consumers** in the same half-hour and adding the sum of the **nominated firm kilowatts** and the **excess kilowatts** (if any) of the **special consumers**

and dividing the product by

the sum of the said maximum number of kilowatts for each Area Board and the chargeable kilowatts in the year of other direct consumers of the Generating Board.

### RESTRICTABLE KILOWATT CHARGE

The above Normal Kilowatt Charge less £4.2.0d. (four pounds two shillings) for each kilowatt of the sum of each maximum **half-hour kilowatt demand** of **special consumers** less the sum of their **nominated firm kilowatts** and less the sum of their **excess kilowatts** (if any).

For the above purposes—

(i) **"the half-hour kilowatt demand" means** twice the number of kilowatt-hours supplied in any half-hour between 7.0 a.m. and 7.0 p.m. on any Monday, Tuesday, Wednesday, Thursday or Friday, or between 7.0 a.m. and 12.0 noon on any Saturday in the year.

(ii) **"special consumer"** means a consumer of the Area Board who has agreed that (without prejudice to any statutory right which the Area Board may have to discontinue the supply of energy) his kilowatt demand can be restricted by the Generating Board for up to 2 hours on any occasion and up to an aggregate of 50 hours in the year provided that

(a) The supply is afforded to the consumer's premises directly from a generating station or substation of the Generating Board through circuits not used for supplies to other consumers.

(b) The difference between the consumer's maximum **half-hour kilowatt demand** and his **nominated firm kilowatts** shall be not less than 25,000 kilowatts.

(c) Suitable provisions have been made in respect of the costs of connection and the technical arrangements for operation, control, and metering, which may vary with local circumstances, and

(d) Prior agreement has been made between the consumer, the Area Board and the Generating Board in each case.

(iii) **"Nominated firm kilowatts"** means the **five minutes kilowatt demand** which in accordance with the above arrangements the **special consumer** is entitled to make during a period of restriction. For this purpose **"five minute kilowatt demand"** means twelve times the number of kilowatt-hours supplied to the **special consumer** in any consecutive five minutes.

(iv) **"Excess kilowatts"** means the amount by which the **nominated firm kilowatts** is exceeded by twelve times the largest number of kilowatt-hours supplied to the **special consumer** in any five minutes (excepting the first five minutes) during any period commencing when the Generating Board indicate (by a signal or otherwise) that they require his demand to be restricted in accordance with the above arrangements, and ending when the Generating Board indicate that normal supply may be resumed.

### RUNNING CHARGE

0.42d. (decimal four two of a penny) for each kilowatt-hour supplied during the year, this charge to be increased or reduced by 0.00055d. (decimal nought nought nought five five of a penny) for each penny (a halfpenny or any greater part of a penny being treated as a penny) by which the fuel cost per ton in the year shall be above or below 60s. (sixty shillings).

For this purpose—

(i) **"Fuel cost per ton"** in any period shall be either

(a) the quotient produced by dividing the aggregate of the product of the **Area fuel cost per ton** in the period and the **number of kilowatt-hours supplied from generation in the Area** in the period, and the product of the **residual cost per ton** in the period and **the number of kilowatt-hours imported into the Area** if any in the period by **the number of kilowatt-hours supplied in the Area** in the period; or

(b) **the Area fuel cost per ton;**
whichever is the less.

(ii) **"The Area"** means the Area of the Area Board taking the supply.

(iii) **"The Area fuel cost per ton"** in any period shall be determined as follows: the total **cost of fuel consumed** in the period at all the Generating Board's stations in **the Area** shall be divided by the total number of tons of **fuel** so consumed and the cost per ton so obtained shall be multiplied by 11,000 and divided by the average gross thermal value of **fuel** so consumed expressed in British thermal units per pound.

(iv) **"Fuel"** shall mean coal, coke and oil fuels but shall not include atomic fuels.

(v) **"The cost of fuel consumed"** shall mean the sums expended for **fuel** consumed plus the cost of any transport, handling preparation or treatment incurred in connection with the delivery of the **fuel** to boiler hoppers or furnaces and in connection with the disposal of the products or residues of combustion, together with the proper proportion of salaries and wages and any contributions for pensions, superannuation and insurance of officers and servants attributable thereto and the amount of any rebate allowed by the suppliers from the price of heavy fuel oil delivered at the Generating Board's stations, such rebate being attributable only to a specific quantity of heavy fuel oil so delivered, less any sums received from the sale of any products or residues of combustion.

(vi) **"The number of kilowatt-hours supplied from generation in the Area"** in any period means the number of kilowatt-hours (being kilowatt-hours generated by the combustion of **fuel**) sent out from all the stations of the Generating Board in **the Area** in the period or **the number of kilowatt-hours supplied in the Area** in the period whichever is the less.

(vii) **"The number of kilowatt-hours supplied in the Area"** in any period shall mean the number of kilowatt-hours supplied in the period by the Generating Board to the relevant Area Board and to other consumers **in the Area.**

(viii) **"The number of kilowatt-hours imported into the Area"** means the amount if any by which **the number of kilowatt-hours supplied in the Area** exceeds **the number of kilowatt-hours supplied from generation in the Area.**

(ix) **"The residual cost per ton"** in any period shall mean the aggregate of—

(A) the quotient produced by dividing the amount by which **the national fuel cost per ton** in the period multiplied by the aggregate of **the number of kilowatt-hours supplied in the** Area of each Area Board in the period exceeds the aggregate of the respective products in the case of each Area Board of (a) **the Area fuel cost per ton** in the period and (b) **the number of kilowatt-hours supplied from generation in the Area** in the period, by the aggregate of the **number of kilowatt-hours imported into the Area** of each Area Board in the period; and

(B) the sum of 6s. (six shillings).

(x) **"The national fuel cost per ton"** in any period shall be determined as follows: the total **cost of fuel consumed** in the period at all the Generating Board's stations shall be divided by the total number of tons of **fuel** so consumed and the cost per ton so obtained shall be multiplied by 11,000 and divided by the average gross thermal value of the **fuel** so consumed expressed in British thermal units per pound.

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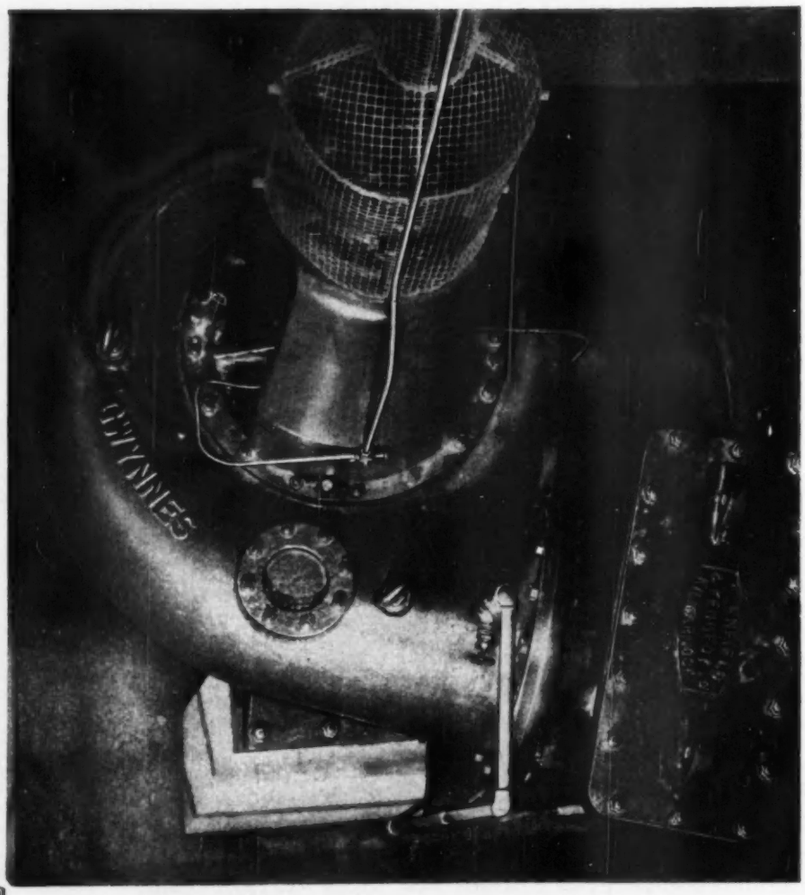


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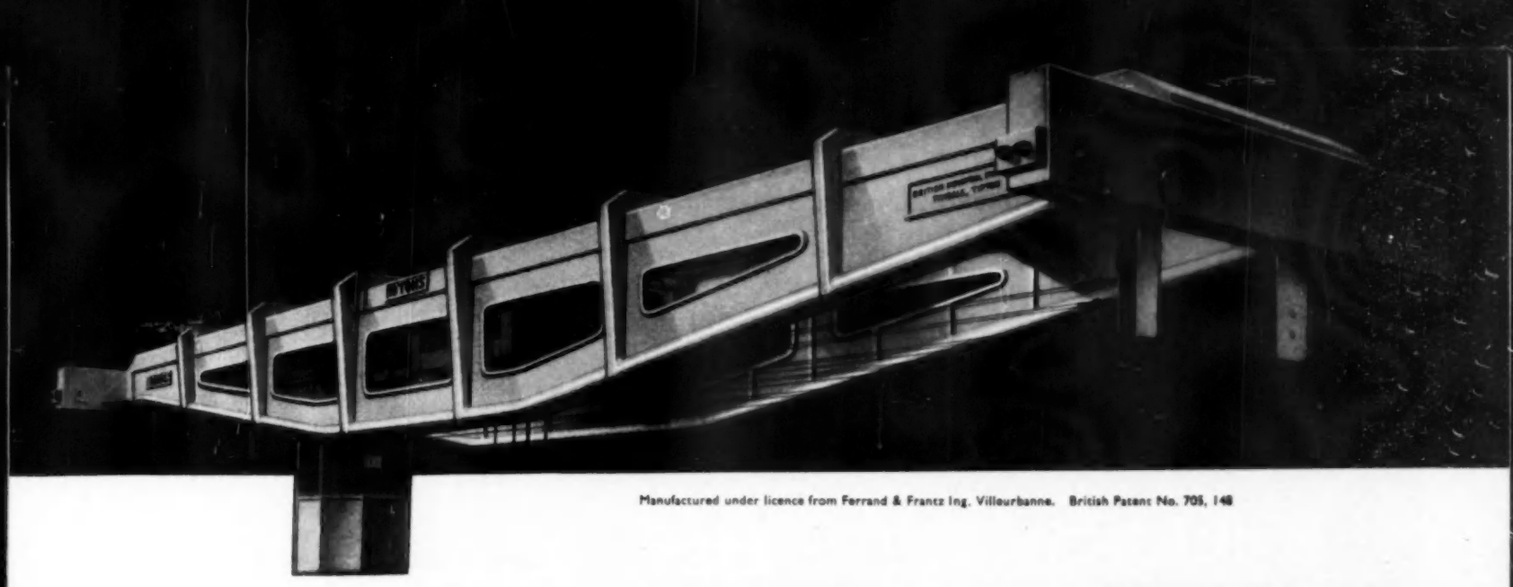

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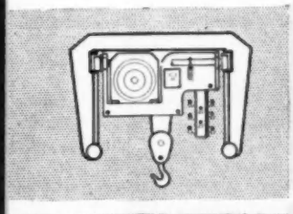

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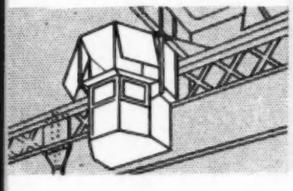

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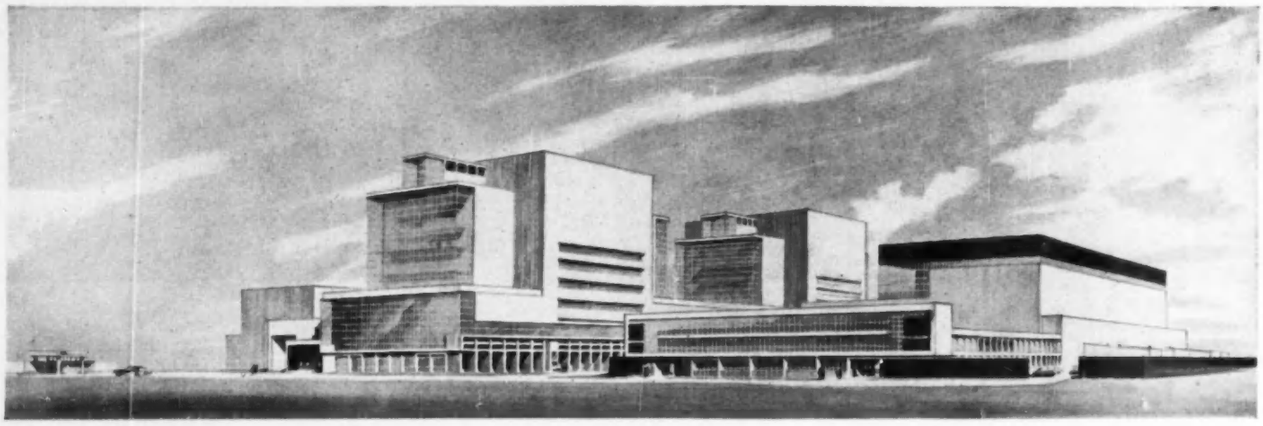

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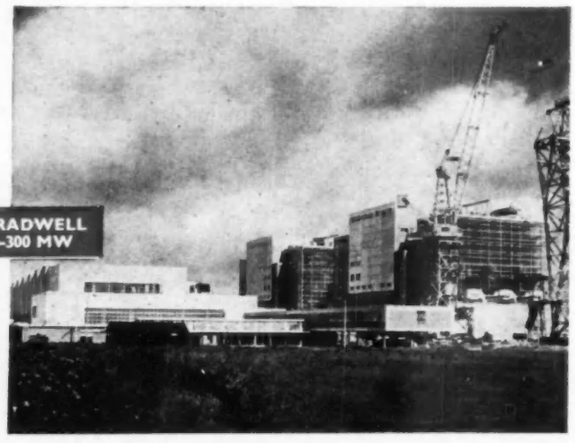
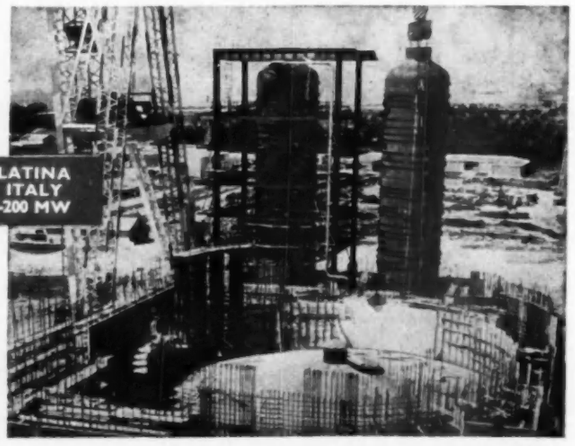
## —550 MW

On the shingled headland of Dungeness, Kent, Britain's newest and largest nuclear power station is being built by The Nuclear Power Group for the Central Electricity Generating Board. The station will incorporate the latest developments in reactor technology and will be the most efficient of its kind. Dungeness is the outcome of experience and know-how, for The Nuclear Power Group are also constructing Britain's first two nuclear power stations at Berkeley and Bradwell and the Italian station at Latina near Rome.



BRADWELL —300 MW

BERKELEY —275 MW



LATINA ITALY —200 MW

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**The Nuclear Power Group**

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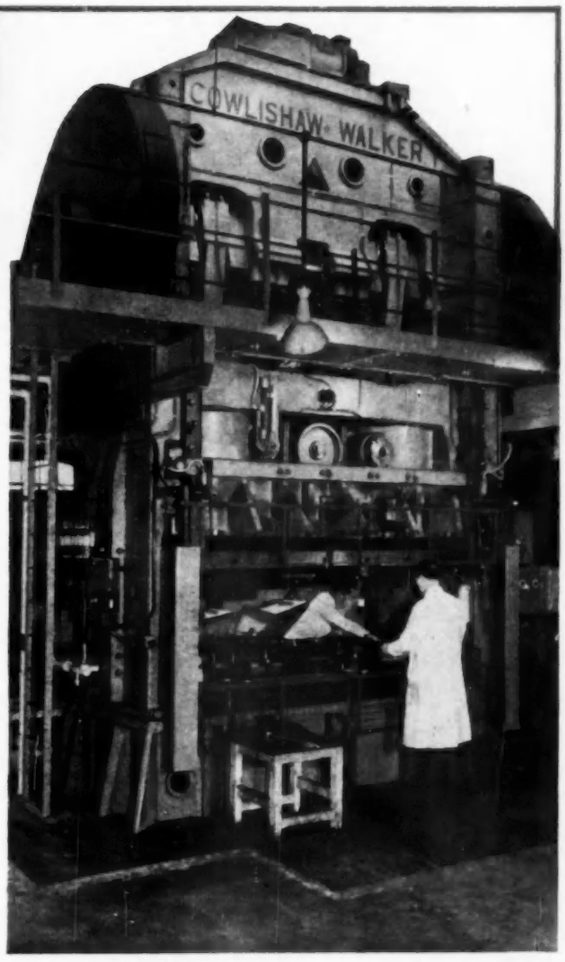


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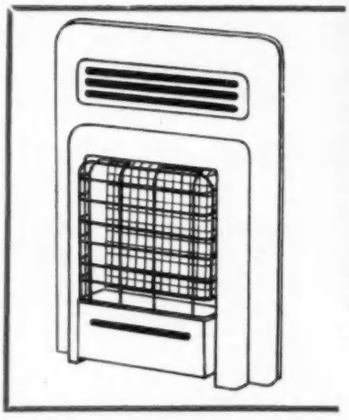
This advanced and highly efficient design of gas fire sends convected warm air to every corner of the room in addition to the normal radiant heat.



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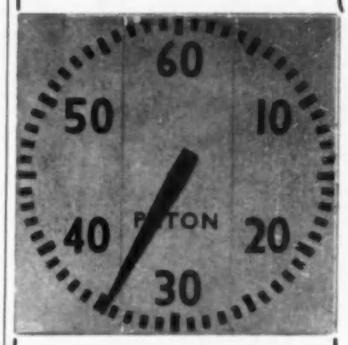


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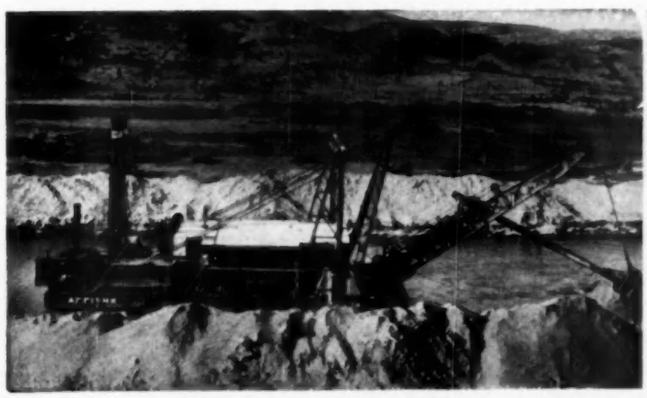

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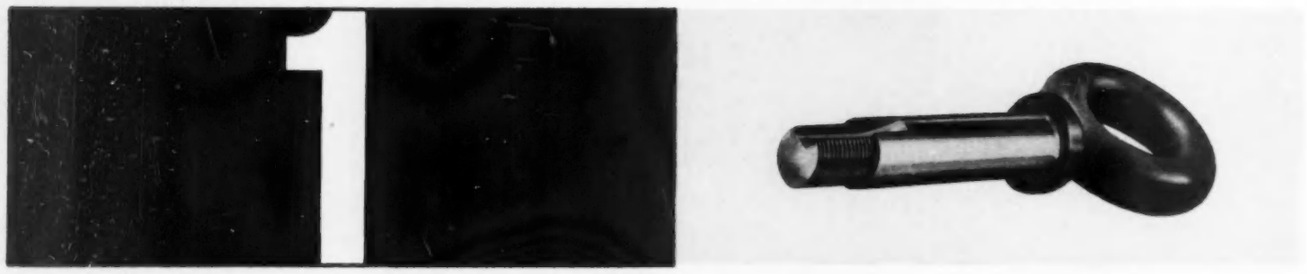


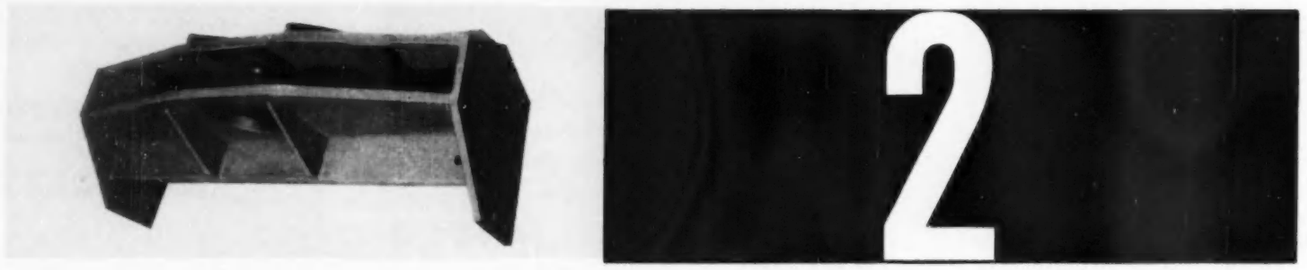


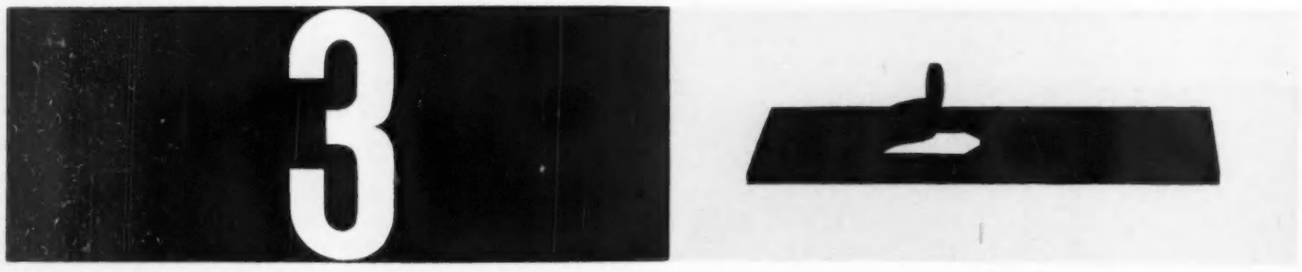


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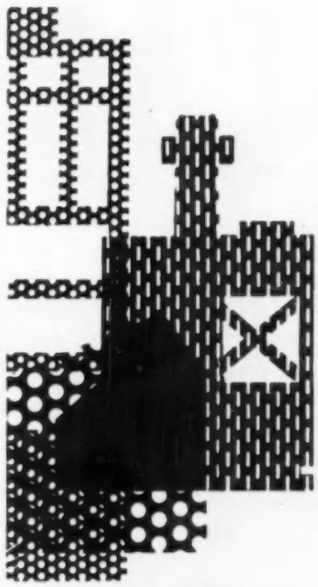

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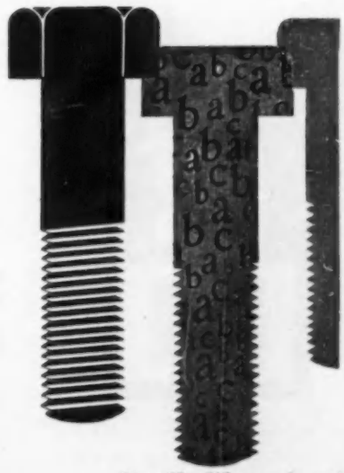

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*high quality*

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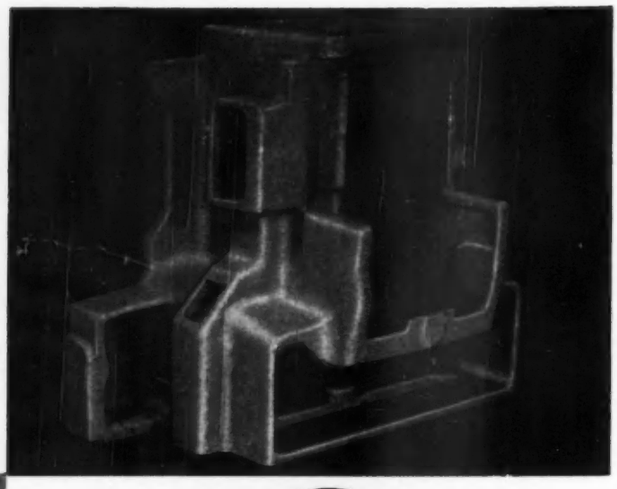
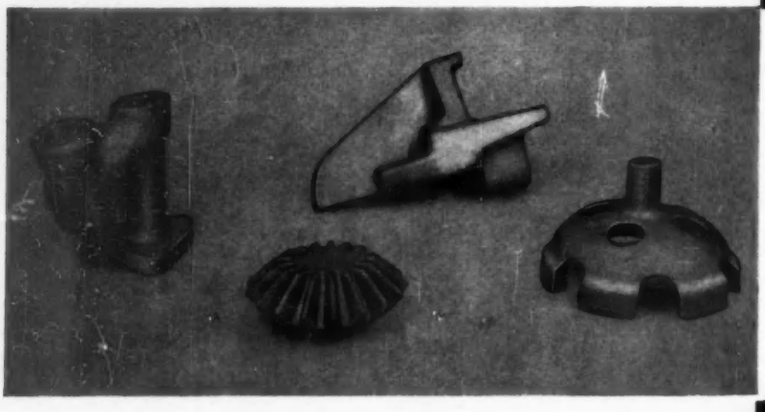
*for Industry*





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**A precision extruded flexible nylon core tube**
**High tenacity braiding**
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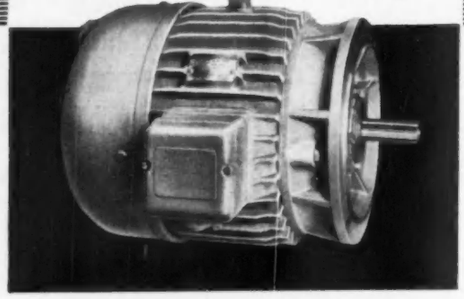

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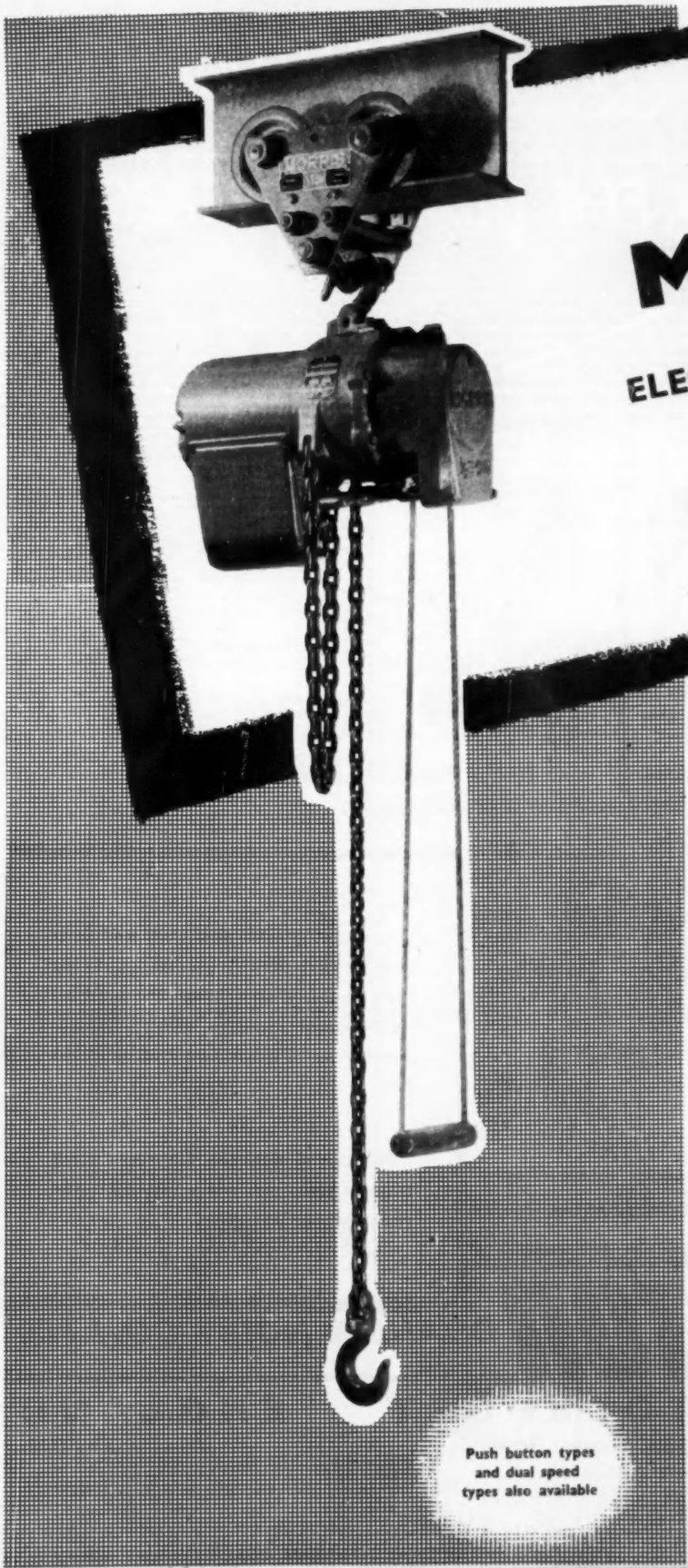

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BALL-BEARING

## ELECTRIC CHAIN HOIST

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SUSPENSION UNIT

A British Product

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***High grade tempered steel gears running in leak-proof oil bath case.***

***Sizes ¼, ½, and 1 ton.***

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For heavier loads

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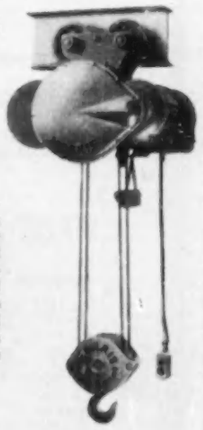
**HOIST-BLOCKS**



These Morris ball-bearing hoist-blocks lift on wire rope and are made in sizes up to 10-tons either as a suspension type or with geared or ungeared runners (as illustrated) for travelling on a steel joist. Several other types are also available including a dual speed model incorporating two speeds in one unit. Write for brochure Section 73/3.

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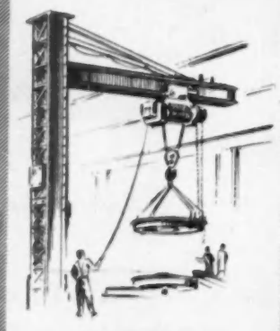

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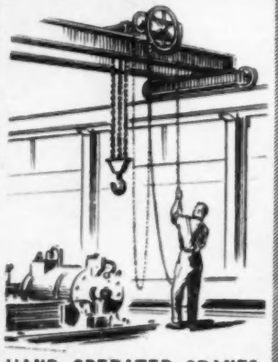
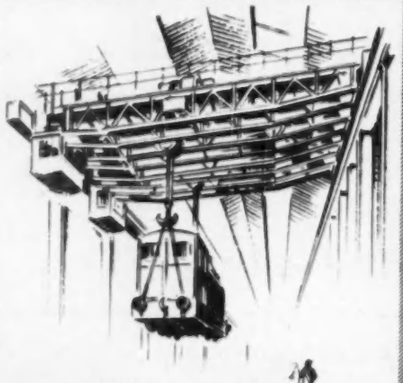


HAND OPERATED CRANES

HAND PULLEY BLOCKS



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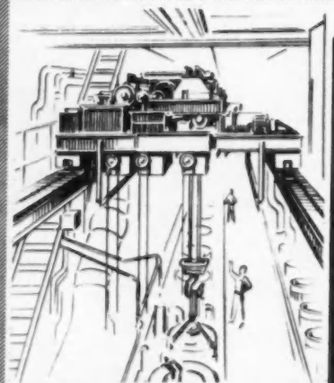

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Our general catalogue illustrates the full range of equipment, and will be sent upon receipt of your instructions.

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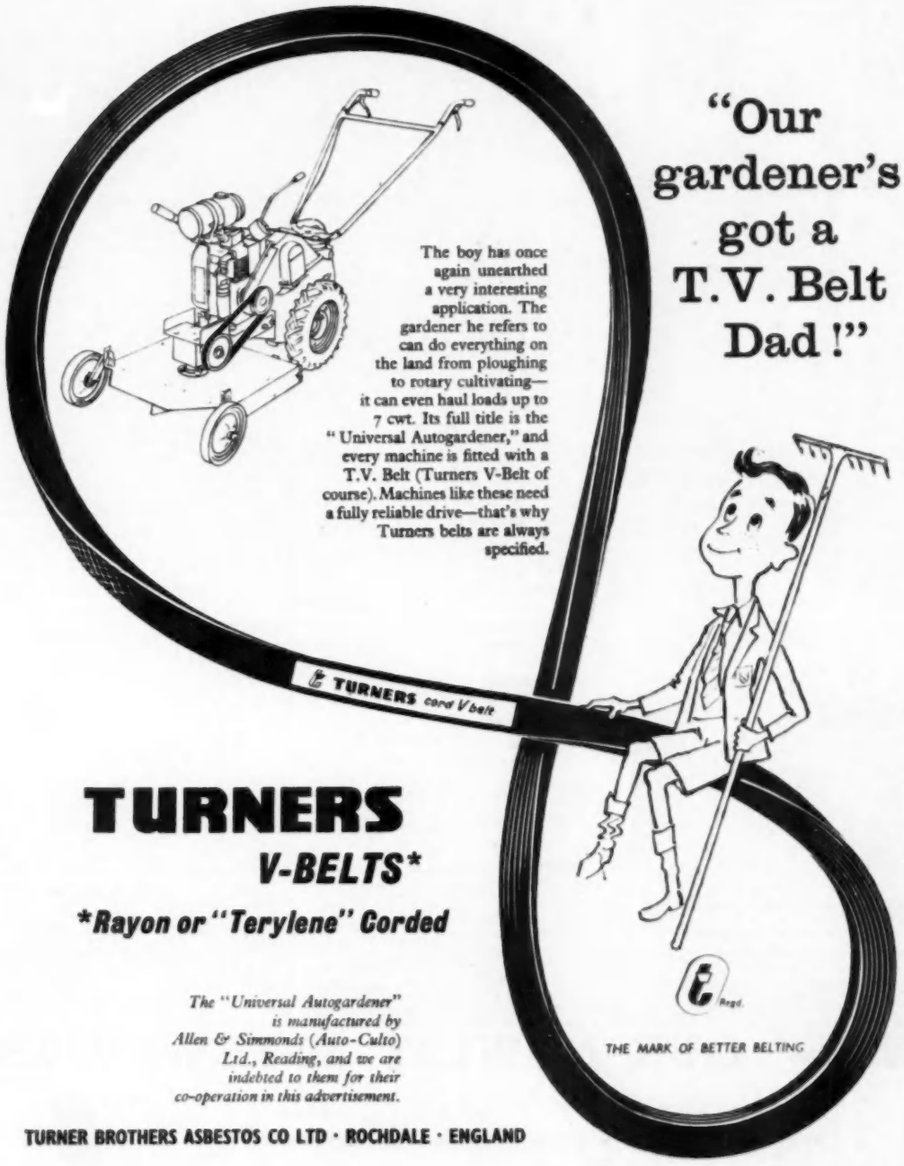


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The boy has once again unearthed a very interesting application. The gardener he refers to can do everything on the land from ploughing to rotary cultivating—it can even haul loads up to 7 cwt. Its full title is the "Universal Autogardener," and every machine is fitted with a T.V. Belt (Turners V-Belt of course). Machines like these need a fully reliable drive—that's why Turners belts are always specified.

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Butane and Propane Storage Vessels, Columns, Cooling and Scrubbing Towers, Air Receivers, Chemical Storage Vessels. Full details supplied on application.

***Also Manufacturers of Ducting and Fabrications. Large Machining Capacity Available.***

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**1,200 H.P.**
THE NEWBURY DIESEL CO. LTD.
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**72"** High **34"** Wide **12"** Deep

- Brand new—Manufactured in our own Works.
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- 6 shelves per bay—Extra shelves 8/- each.
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*All-steel, stove enamelled dark green*

Our most popular unit, with 54 drawers, each 5" wide, 3" high, 11½" long, each drawer fitted with 1 free divider and drawer card. Extra dividers can be obtained at 6d. each Cards supplied free. Overall size of unit, 42" high, 35" wide, 11½" deep.

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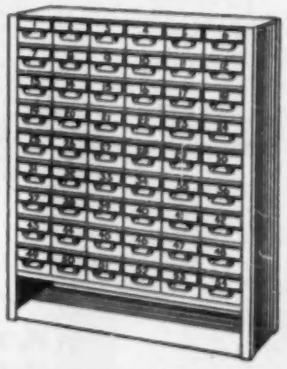

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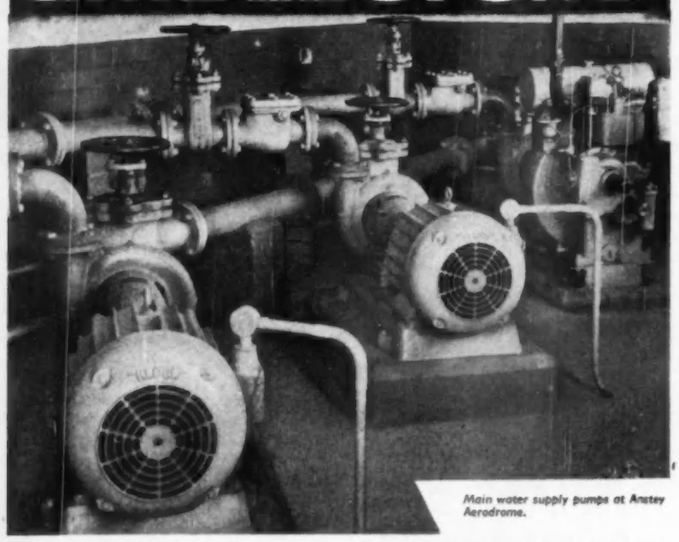

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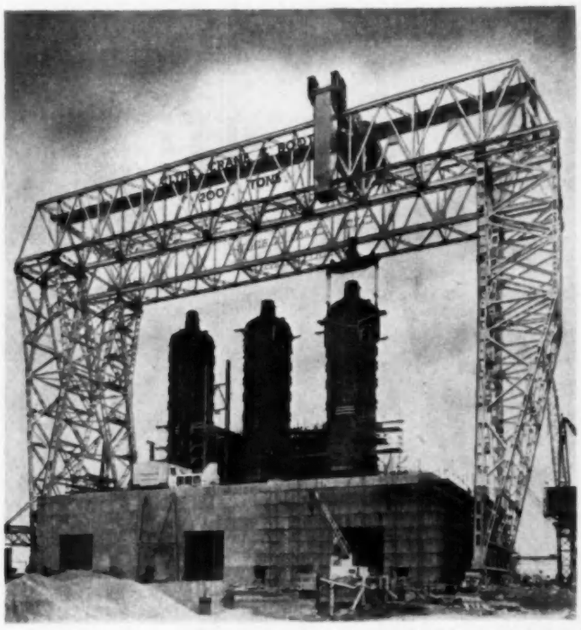

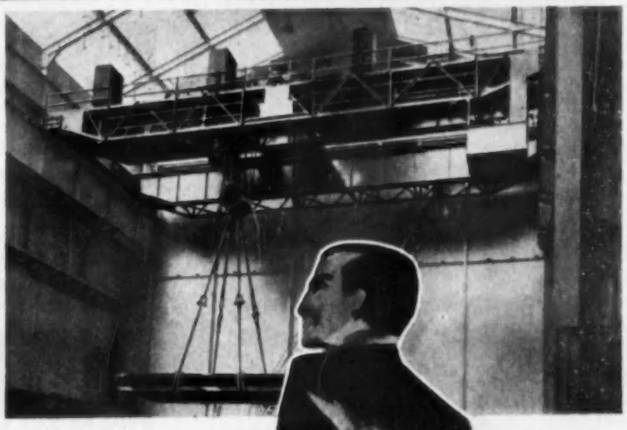

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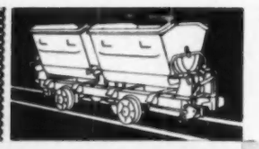

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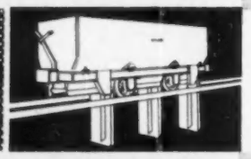

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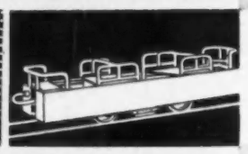

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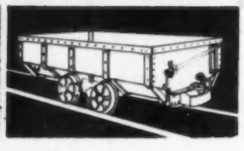

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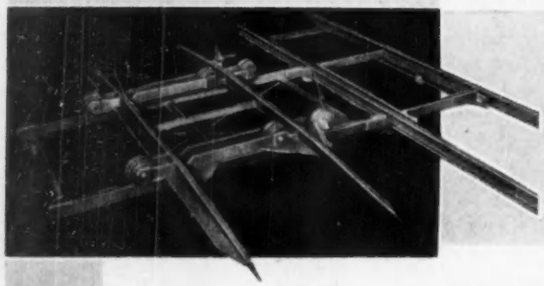

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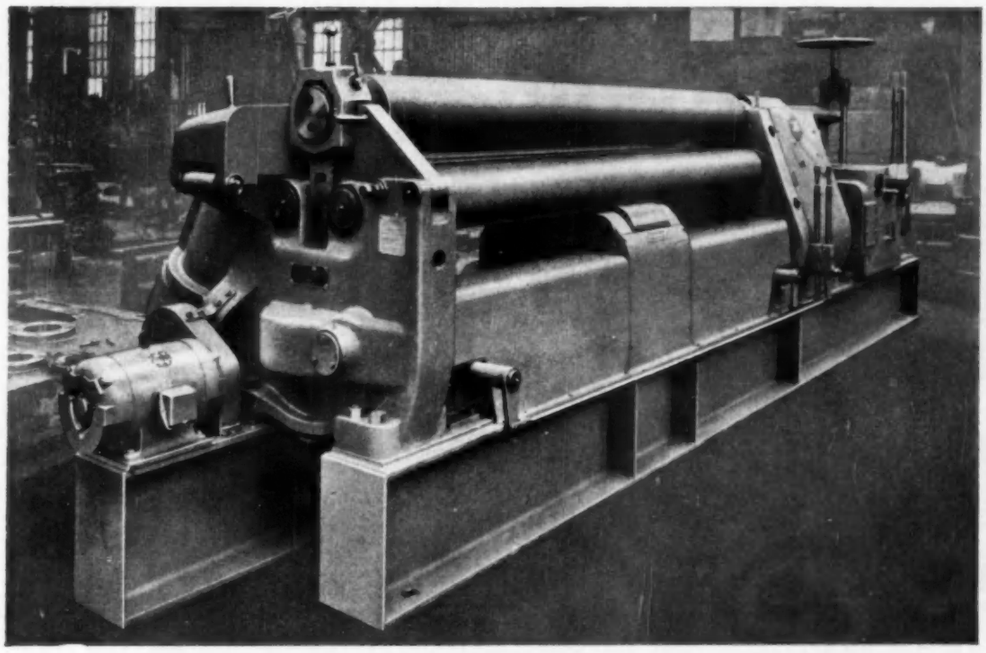

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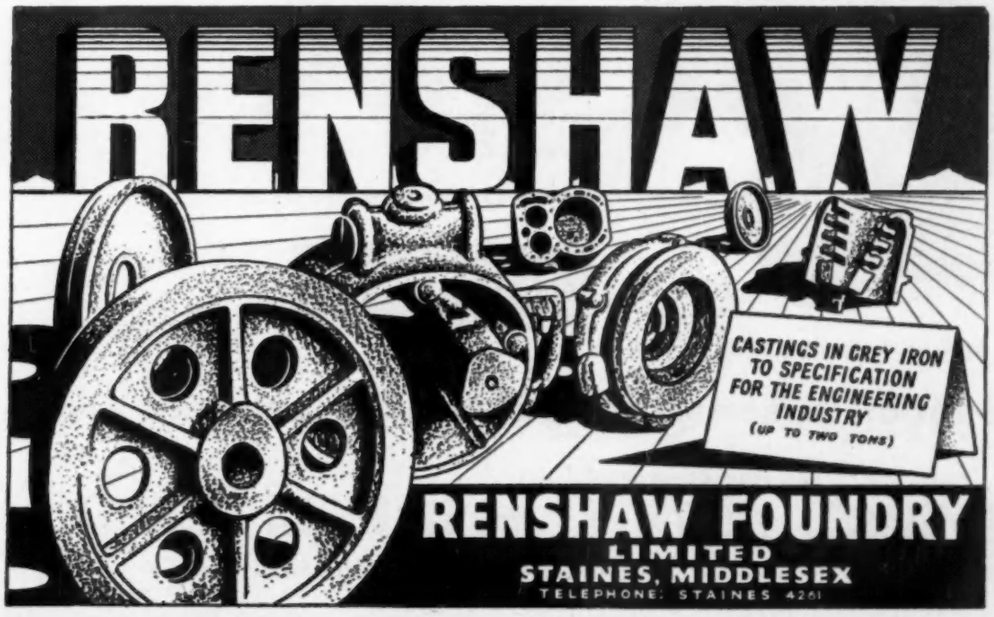


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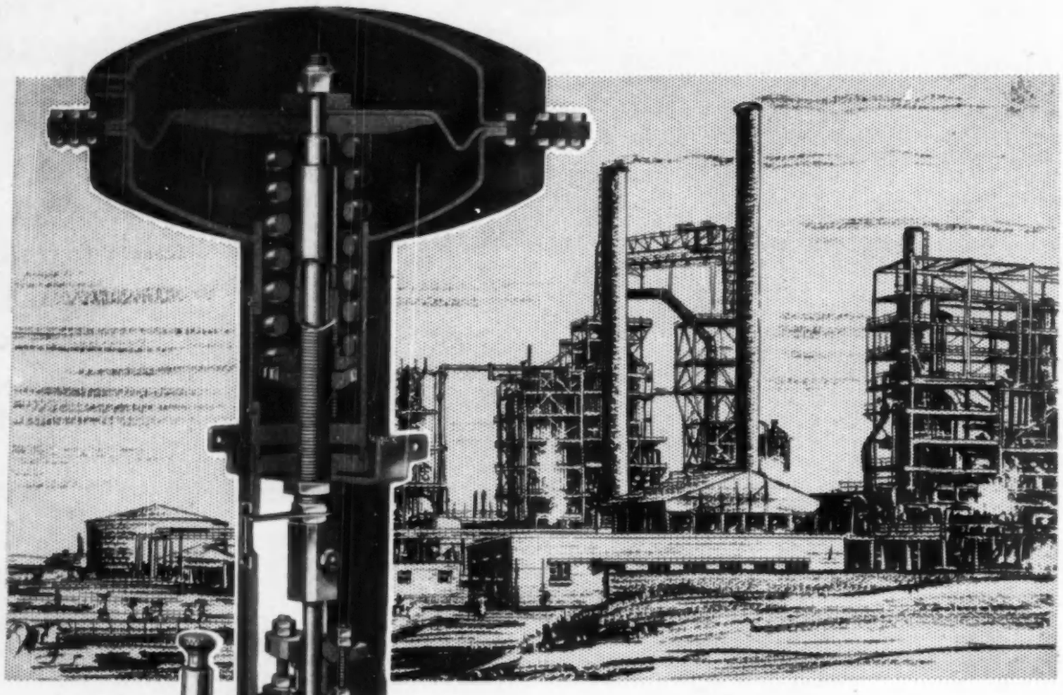

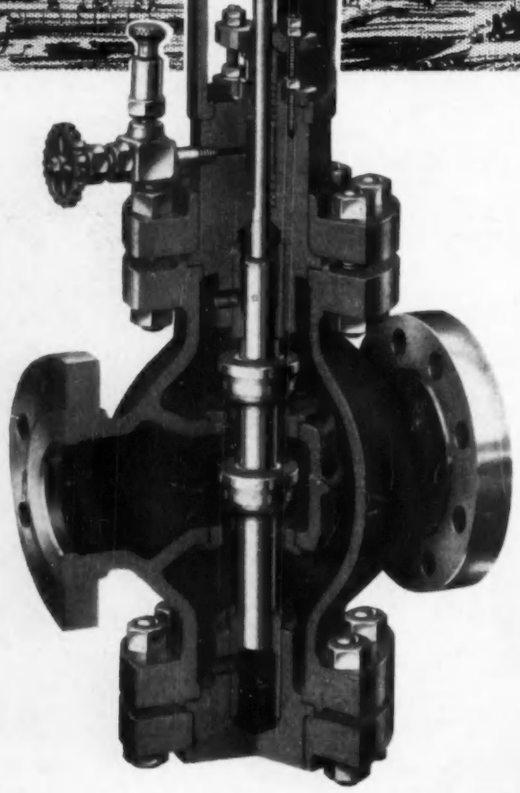

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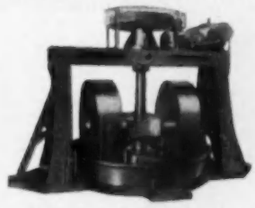

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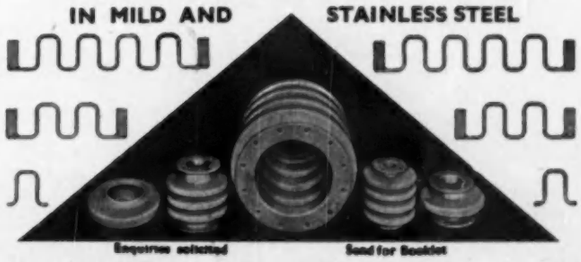

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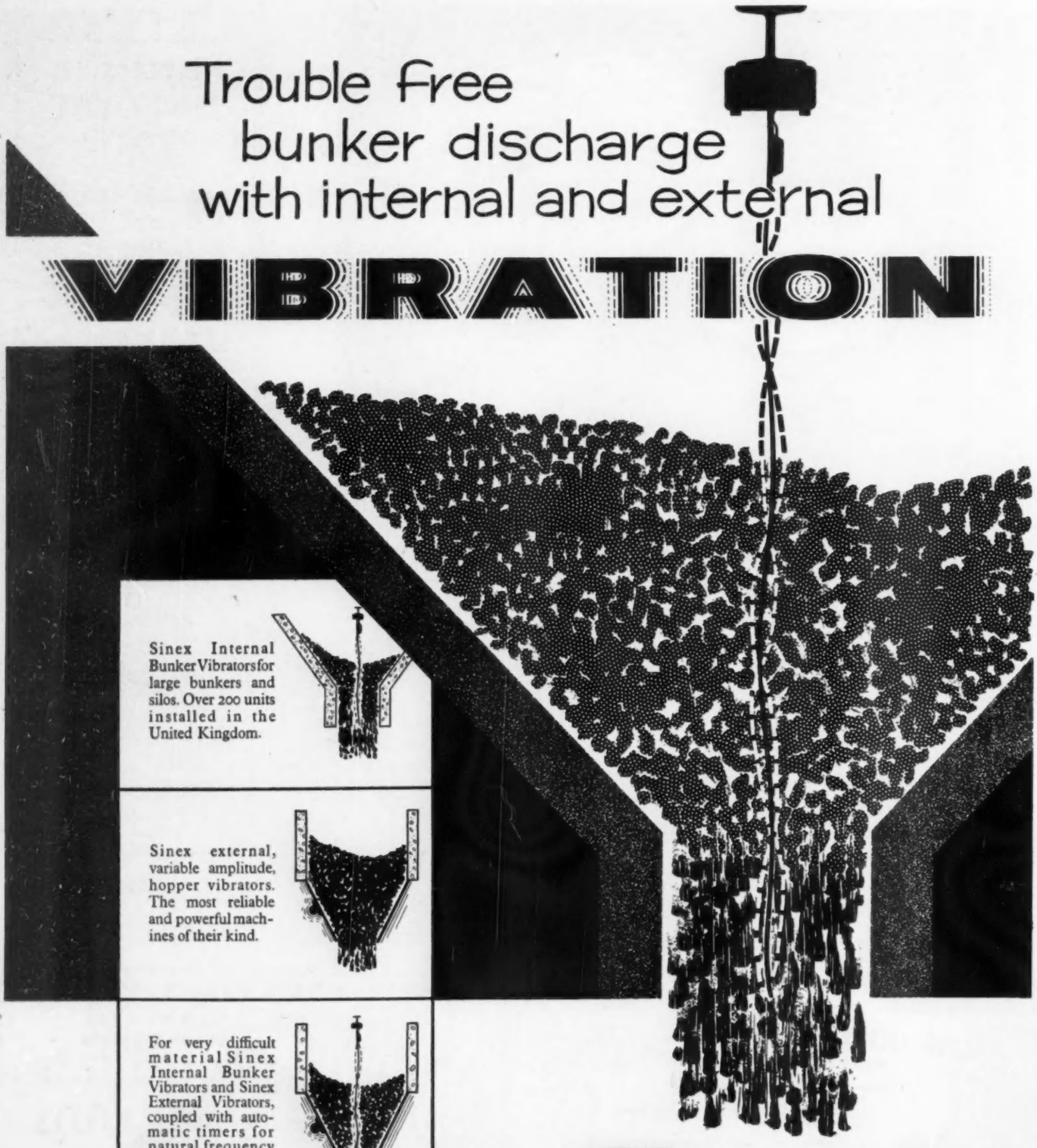

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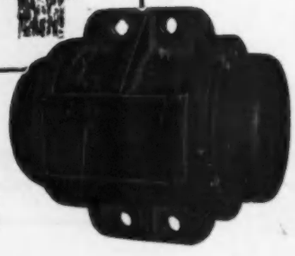

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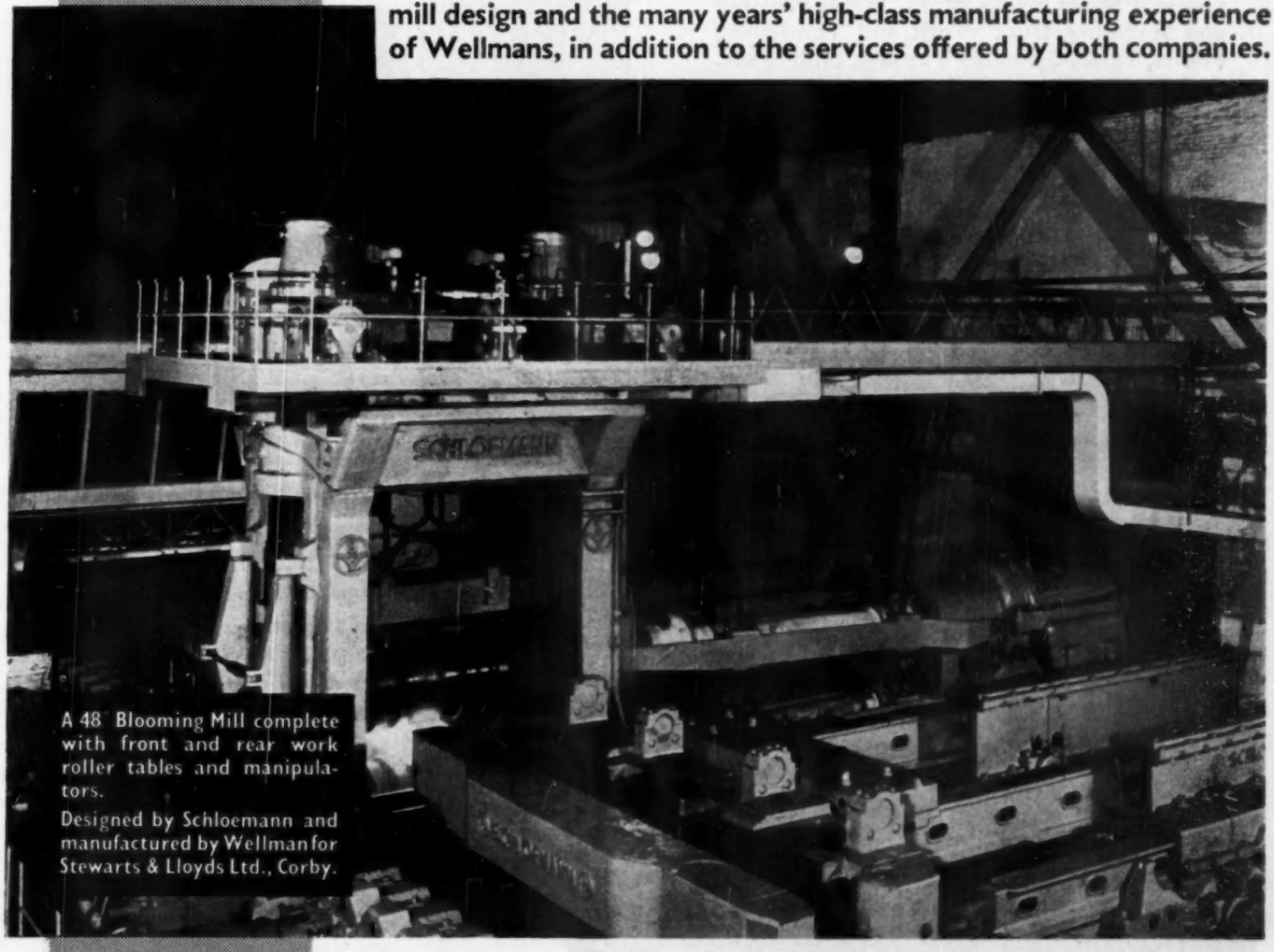


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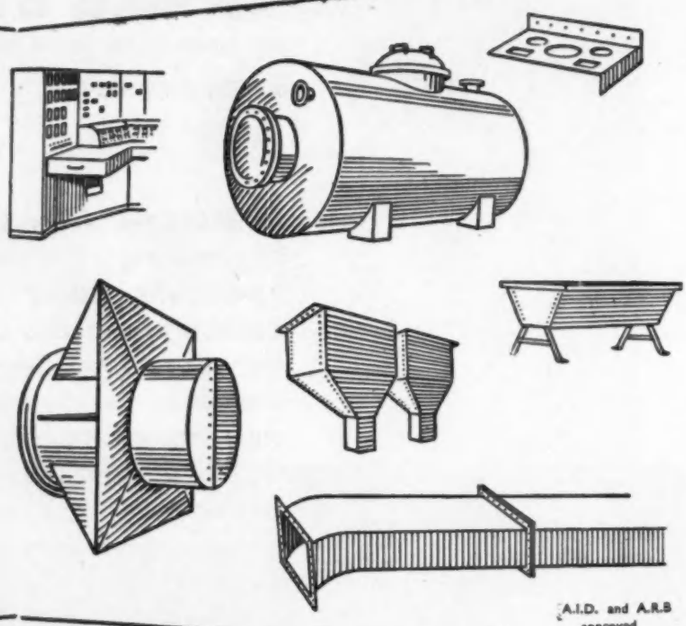

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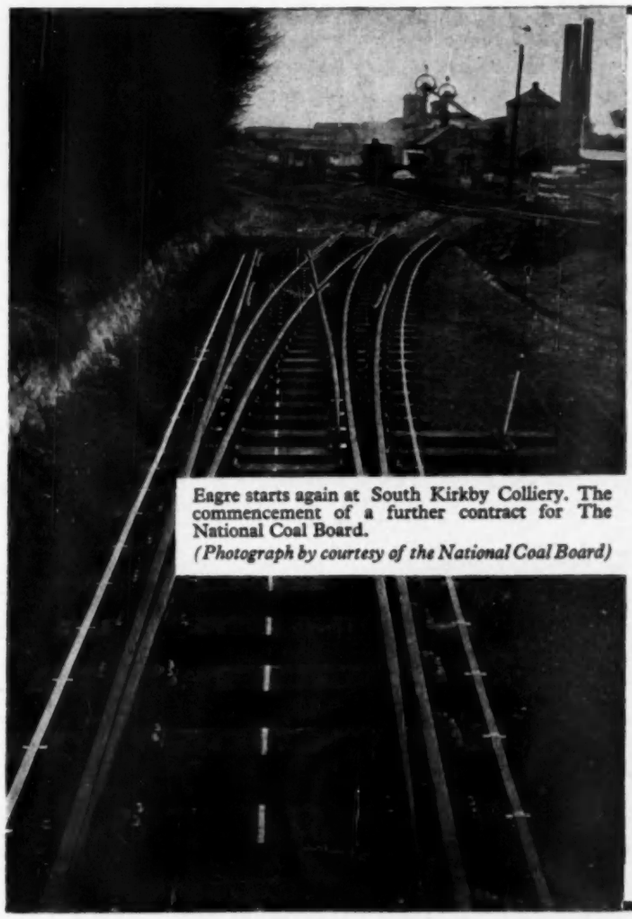

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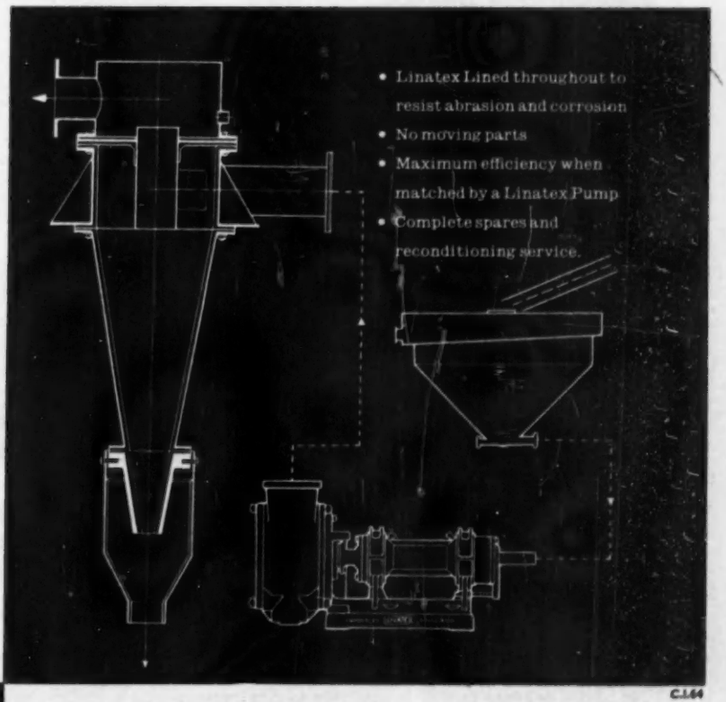
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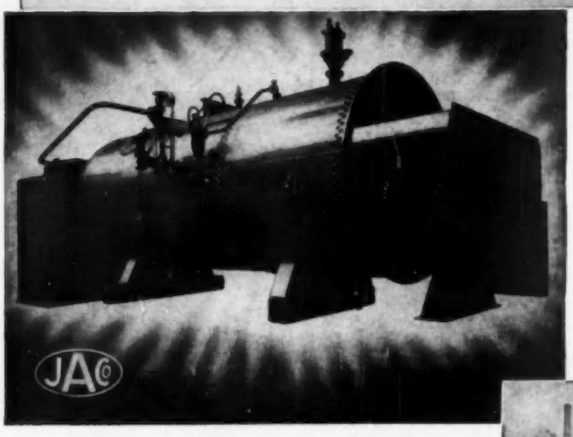

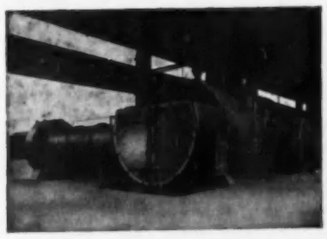

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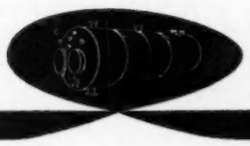

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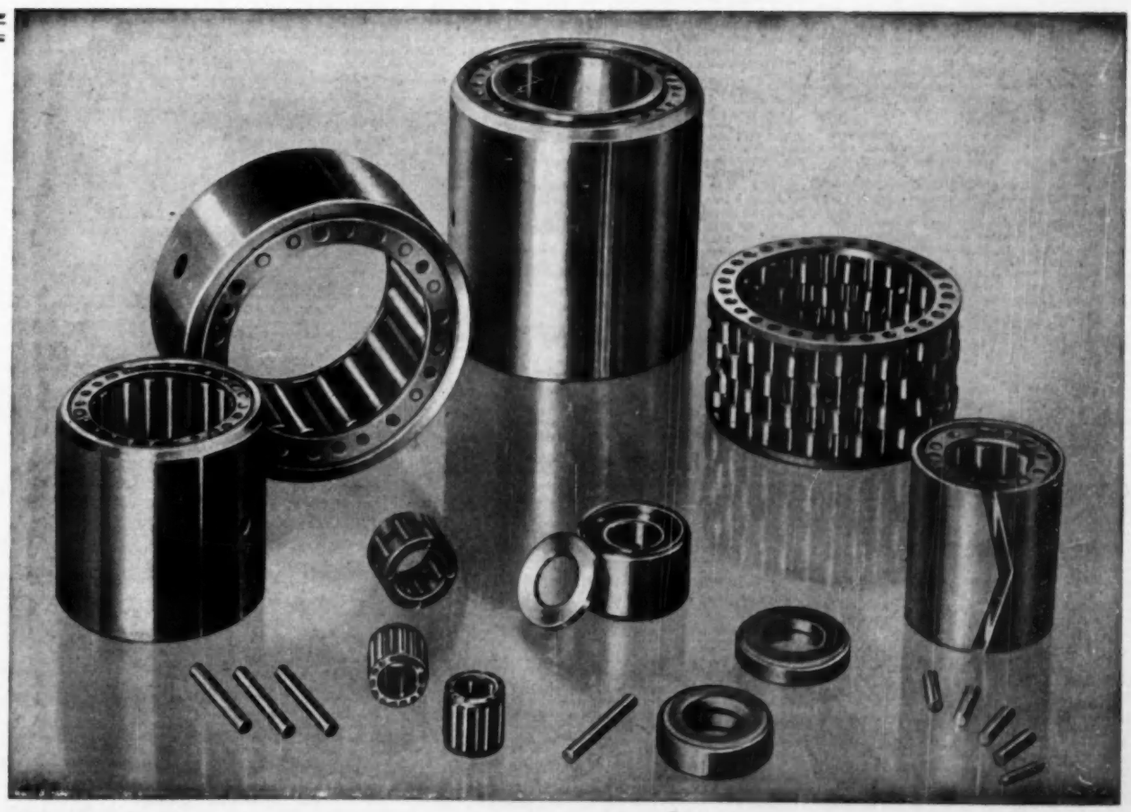

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**Lineage Rate.** 4/6 per line of approximately 6 words. **Minimum** 18/-. **Inch Rate.** 54/- per single column inch and pro rata. 12 lines to 1 inch.

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**Use of Box Number.** 2/- which includes forwarding of replies.

**Copy Dates.** Tuesday for publication on Friday of the same week. If proofs are wanted, copy is required on Thursday for publication on Friday of the following week.

*Advertisements for publication should be addressed to:*—**Classified Advertisement Dept., "THE ENGINEER," 28 Essex Street, Strand, London, W.C.2**

*Urgent advertisements may be telephoned to CENtral 6565.*

## PUBLIC APPOINTMENTS

### UNIVERSITY OF WALES

#### UNIVERSITY COLLEGE OF SWANSEA

#### DEPARTMENT OF ENGINEERING

#### APPOINTMENTS

Owing to the large expansion of the Departmental facilities for both teaching and research, a number of appointments will be made to the Staff both immediately and from October 1st, 1961. Applications are invited from graduates in Engineering, Physics, Metallurgy or Applied Mathematics for the following posts :

Civil Engineering :
Professor B. G. Neal.

LECTURER or Assistant Lecturer with interests in any branch of Civil Engineering.

Civil or Mechanical Engineering

LECTURER or Assistant Lecturer with special interests in Strength of Materials and related fields.

Mechanical Engineering :
Professor R. H. Macmillan.

TWO LECTURERS or Assistant Lecturers, one with particular interests in the fields of Heat Transfer and Thermodynamics, the other preferably having experience in the Design of Machines, but applicants with other interests will be considered.

RESEARCH DEMONSTRATOR to undertake a limited amount of teaching and pursue supervised research preferably in Heat Transfer, Hydrodynamic power transmission, Fatigue or creep.

Electrical Engineering :
Professor W. Fishwick.

LECTURER or Assistant Lecturer with special interests in Control Engineering, Electrical Apparatus or related fields.

LECTURER or Assistant Lecturer with interests in any branch of Electrical Engineering, including Theoretical Electro-technics.

Qualifications for, and further details of, these posts are as follows :

LECTURER. Applicants should hold a good Honours degree and have not less than three years post-graduate experience in research or industrial design. Excellent facilities exist for research.

ASSISTANT LECTURER. Applicants should hold a good Honours degree and have at least one year's industrial or post-graduate experience. Research is strongly encouraged and the assistant may register for a Ph.D. degree.

RESEARCH DEMONSTRATOR. Applicants should have obtained a good Honours degree and have had at least one year's industrial or post-graduate experience. The appointment will be tenable for three years, during which time the holder will be expected to work for the Ph.D. degree, submitting a thesis at the end of the period.

Salaries are on the following scales, to which are added F.S.S.U. benefits and family allowances.

Lecturer . £1050 by £50 to £1400 by £75 to £1850 per annum.

Assistant Lecturer : £800 by £50 to £950 per annum.

Research Demonstrator : £700 per annum.

Further particulars can be obtained from the Registrar, University College, Singleton Park, Swansea, by whom applications (two copies) must be received not later than Saturday, January 21, 1961.

E7418

### BRADFORD INSTITUTE OF TECHNOLOGY

#### APPOINTMENTS

Applications are invited for the following posts:—

READER IN MECHANICAL ENGINEERING

Candidates should possess the qualifications and experience to direct research and post-graduate work and to take a leading part in advanced teaching. Importance will be attached to industrial and research experience. Adequate facilities will be given to undertake research and suitable technical assistance and equipment are available.

Salary £1800 to £2100 per annum (or above in special cases).

PRINCIPAL LECTURER IN MECHANICAL ENGINEERING

Candidates should be qualified to teach to final degree and Diploma in Technology standard and should have adequate research and industrial experience. The successful candidate will be expected to assist the Head of the Department with the organisation and administrative work of the Department and will be encouraged to develop industrial contacts.

Salary £1750 to £1900 per annum.

Previous industrial or research experience at a suitable level will be taken into account in fixing the commencing salary.

Senior members of staff are encouraged to undertake consultant work in industry and may retain fees paid for such work.

Further particulars and forms of application may be obtained from the Registrar, Bradford Institute of Technology, Bradford, 7.

HENRY PATTEN,
Clerk to the Governors.

E7465

## PUBLIC APPOINTMENTS

### UNIVERSITY OF NEW SOUTH WALES

#### AUSTRALIA

#### THE NUFFIELD RESEARCH CHAIR OF MECHANICAL ENGINEERING

The University invites applications for appointment to the NUFFIELD RESEARCH CHAIR OF MECHANICAL ENGINEERING, which will become vacant early in 1961.

A salary of not less than £A4279 p.a. will be paid to the successful applicant.

Applicants must have high academic qualifications and experience in some field of Mechanical Engineering.

The research background and interests of applicants are not specified, but the University will be interested in applicants working in the fields of thermodynamics and fluid mechanics.

The successful applicant will be situated within the School of Mechanical Engineering of which the Head is Professor A. H. Willis, and will be expected to supervise an appropriate academic group in the School and to concentrate on research and post-graduate activity in that field.

Subject to the consent of the Council of the University, professors may engage in a limited amount of higher consultative work.

The successful applicant will be eligible subject to satisfactory medical examination to join the superannuation scheme, which provides a maximum pension of £A2184 p.a.

Professors are eligible for six months' study leave on full salary after three years of service, or twelve months after six years of service.

The University reserves the right to fill the Chair by invitation.

With approval of the University and its bankers, married men may be assisted by loans to purchase a home.

First class ship fares to Sydney of the appointee and his family will be paid.

Four copies of applications including the names of 3 referees and a recent photograph of the applicant should be lodged with the Agent General for New South Wales, 56-57 Strand, London, W.C.2 England, and a copy forwarded to the Appointments Section, The University of New South Wales, Box 1, Post Office, Kensington, New South Wales, Australia, by airmail to reach there before 10th February, 1961. Applicants outside the United Kingdom need only submit one copy of their application to the London address.

E7454

### UNIVERSITY OF AUCKLAND

#### NEW ZEALAND

#### CHAIR OF ENGINEERING (MECHANICAL)

Applications are invited for the above-mentioned appointment, which carries the right of private consultative practice under certain conditions.

The salary will be £2800 per annum and travel and removal expenses will be allowed within specified limits.

Unfurnished accommodation is provided at a moderate rental.

Further particulars and information as to the method of application should be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

Applications close, in New Zealand and London, on 7th February, 1961.

E7456

### LEWISHAM GROUP HOSPITAL MANAGEMENT COMMITTEE

#### SUPERINTENDENT ENGINEER

Applications are invited for the position of SUPERINTENDENT ENGINEER who will be responsible for the operation, maintenance and co-ordination of the engineering services and activities, in this large and important group of hospitals; the supervision of maintenance works and staff, and the keeping of all necessary records, &c. Post vacant 1 April, 1961.

Applicants should be qualified in accordance with the Ministry of Health requirements.

Salary scale : £1130 to £1325, plus £50 London Weighting Allowance. In addition, at the present time, a long hours gratuity at the rate of 6½ per cent of salary is also payable.

Applications, giving details of qualifications and experience, present and previous posts, &c., together with the names and addresses of two referees, should be sent to the Group Secretary, Lewisham Hospital, Lewisham, London, S.E.13, by not later than 21 January, 1961.

E7430

## PUBLIC APPOINTMENTS

### METROPOLITAN WATER, SEWERAGE AND DRAINAGE BOARD OF NEW SOUTH WALES

#### AUSTRALIA

#### ENGINEERS

Applications are invited from graduates or diplomates (preferably under 30 years of age) in Engineering for appointment to the Engineering staff of the Metropolitan Water, Sewerage and Drainage Board of New South Wales. Because of accommodation difficulties, vacancies exist only for single men and married men without children.

Minimum commencing salary £A1265 p.a. for a diplomate and £A1383 p.a. for a graduate, with incremental progression, subject to satisfactory service, to £A2025 p.a. Progression beyond this rate is by appointment as vacancies arise.

The main requirement is for Civil Engineers, who have just completed training but consideration will also be given to those with some experience and to graduates and diplomates in Mechanical, Electrical and Chemical Engineering.

Appointees will be employed on the investigation, design, construction or maintenance of water, sewerage and storm-water drainage projects in the Sydney or Wollongong areas. No country service is involved.

Superannuation Scheme. Good leave conditions. Successful applicants will be nominated for travel under the Assisted Passage Scheme. The cost of the passage is £10 per adult.

For further particulars and application forms, please write to Agent General for New South Wales, 56, Strand, London, W.C.2, quoting No. 44/97.

E7373

### HUNTINGDONSHIRE COUNTY ARCHITECT'S DEPARTMENT

#### TECHNICAL ASSISTANT HEATING ENGINEER

Applications are invited for the above appointment within Grade A.P.T. III (£960 to £1140) or Grade IV (£1140 to £1310) according to qualifications and experience.

The person appointed will be a member of the Engineering Section of the department, and his duties will consist of all works connected with heating installations related to both small and large building projects. Applicants must be competent draughtsmen with experience in the design of heating and allied services and they should hold the Ordinary National Certificate in mechanical engineering or be graduates of the Institution of Heating and Ventilating Engineers.

Application forms may be obtained from S. M. Holloway, A.R.I.B.A., County Architect, County Buildings, Huntingdon, and completed forms should be returned to the undersigned by Tuesday, 17th January, 1961.

A. C. AYLWARD,
Clerk of the County Council.

County Buildings, Huntingdon.

E7463

### NORTH WEST METROPOLITAN REGIONAL HOSPITAL BOARD

#### DEPUTY REGIONAL ENGINEER

Applications are invited for the post of DEPUTY REGIONAL ENGINEER. He will be required to act for the Regional Engineer over the full range of the services for which he is responsible and will be responsible for the day-to-day supervision of the Engineering Department. The Board is engaged on plans for a considerable expansion of the Hospital building programme and the Regional Engineer's Department has recently been reorganised to provide for four engineering teams working on a project basis. There will eventually be an engineering staff of about 45.

Applicants must be Corporate Members of the Institution of Mechanical Engineers and/or Institution of Electrical Engineers.

Salary scale : £2015 to £2415.

Apply, stating age, qualifications (with dates) and experience, with names and addresses of two referees, to Secretary, North West Metropolitan Regional Hospital Board, 40, Eastbourne Terrace, London, W.2, quoting reference 878 by 11th January.

E7452

## PUBLIC APPOINTMENTS

### TRENT RIVER BOARD

#### APPOINTMENT OF ASSISTANT ENGINEER II

Applications are invited for the appointment of ASSISTANT ENGINEER II in the Board's Divisional Office at Tamworth. Salary—A.P.T. Grades I–III : (£645 to £1140) or A.P.T. III–IV : (£960 to £1310).

N.J.C. service conditions with car allowance on "Essential User" scale and Assisted Car Purchase Scheme is operated by the Board. The commencing salary within the Grades mentioned will be according to qualifications and experience but normally the appointment will be made in the lower half of the ranges.

The successful applicant will be engaged mainly on the design and supervision of river improvement schemes carried out by either contract or direct labour. Applications from University students who expect to graduate in 1961 will also be considered.

Applications, including copies of testimonials or names of two referees, to the Engineer, Trent River Board, 206, Derby Road, Nottingham, by 16th January, 1961.

IAN DRUMMOND,
Clerk of the Board.

E7419

### ST. JAMES' HOSPITAL

#### BALHAM, LONDON, S.W.12

(562 BEDS)

#### SENIOR ENGINEER

SENIOR ENGINEER required for this busy general hospital. Candidates should hold 1st Class Certificate in Marine Engineering or equivalent Naval or Ordinary National Certificate including Heat and Heat Engines. Whitley Council conditions and salary scale £745 to £895 inclusive (over 26 years). Residential accommodation available. Applications including age, qualifications, experience and two referees to Group Secretary at above address by 10th January.

E7460

## TENDERS

### WEST CORNWALL WATER BOARD

#### HAYLE WATER SCHEME

#### CONTRACT NO. 11

#### PHILLACK TOWANS RESERVOIR AND PIPELAYING

The Board invites FIXED PRICE TENDERS from EXPERIENCED CONTRACTORS for the construction of a CONCRETE SERVICE RESERVOIR with a capacity of 150,000 gallons at Phillack Towans, and excavating for, Supplying, Laying, Jointing, and the Maintenance of about 1150 yards of 6in. and 4in. diameter asbestos cement pipes, together with valves and fittings &c.

The reservoir is rectangular in plan with normally reinforced concrete walls, columns and flat slab roof.

The General Conditions, Specification, Bill of Quantities and Form of Tender for this Contract, prepared by the Engineers, Herbert Lapworth Partners, 25, Victoria Street, Westminster, S.W.1, may be obtained from the UNDERSIGNED on or after Wednesday, the 11th January, 1961, on receipt of a cheque for £5 made payable to the West Cornwall Water Board, which sum will be returned on receipt of a bone fide Tender.

Tenders, together with all documents received are to be enclosed in a sealed cover endorsed "Hayle Water Scheme—Tender for Contract No. 11—Phillack Towans Reservoir and Pipelaying" and addressed to the UNDERSIGNED and delivered not later than 10 a.m. on Monday, 30th January, 1961.

Only Tenders from firms experienced in this type of work will be considered.

The Board do not bind themselves to accept the lowest or any Tender.

E. O. WHEALE,
Clerk to the Board.

Municipal Buildings, Penzance, Cornwall.
16th December, 1960.

E7442

## TENDERS

### WEST CORNWALL WATER BOARD

**DRIFT WATER SCHEME**

**CONTRACT NO. 7—PIPELAYING**

The Board invites FIXED PRICE TENDERS from EXPERIENCED CONTRACTORS for the following work :

CONTRACT No. 7. Supplying, Excavating for, Laying, Jointing, Maintenance and ancillary works, for about 15 miles of SPUN IRON MAINS with Flexible Joints, including all valves and fittings, as follows :

Section A

| | | |
|---|---|---|
| About | 970 yard of | 12in. diameter. |
| ,, | 10,140 ,, ,, | 10in. ,, |
| ,, | 2,380 ,, ,, | 8in. ,, |
| ,, | 695 ,, ,, | 6in. ,, |
| ,, | 370 ,, ,, | 4in. ,, |
| ,, | 330 ,, ,, | 3in. ,, |

Section B

| | | |
|---|---|---|
| About | 2,315 yards of | 6in. diameter. |
| ,, | 7,405 ,, ,, | 4in. ,, |
| ,, | 1,865 ,, ,, | 3in. ,, |

The General Conditions, Specification, Bill of Quantities and Form of Tender for this Contract, prepared by the Engineers, Herbert Lapworth Partners, 25, Victoria Street, Westminster, S.W.1, may be obtained from the UNDERSIGNED on or after Wednesday, the 11th January, 1961, on receipt of a cheque for £5 made payable to the West Cornwall Water Board, which sum will be returned on receipt of a bona fide Tender.

Tenders, together with all documents received are to be enclosed in a sealed cover endorsed " Drift Water Scheme—Tender for Contract No. 7—Pipelaying " (Section A and B separately) and addressed to the UNDERSIGNED and delivered not later than 10 a.m. on Monday, 30th January, 1961.

Only Tenders from firms experienced in this type of work will be considered.

The Board do not bind themselves to accept the lowest or any Tender, and reserve the right to accept separate Tenders for Section A or B or one Tender in respect of the whole of the work.

E. O. WHEALE,
Clerk to the Board.

Municipal Buildings,
Penzance,
Cornwall.
16th December, 1960. E7441

### INDIA STORE DEPARTMENT

The Office of the Director General, India Store Department, Government Building, Bromyard Avenue, Acton, W.3, invite TENDERS for the following :—

FIVE TRIMMING MACHINES fully Tooled Up, to cut off and chamfer, drawn 30mm. shell cases.

Specifications &c., relative to the above specification, can be obtained from the Co-ordination Branch, India Store Department, Bromyard Avenue, Acton, W.3, at a cost of 10s. per set of Tenders and is not refundable.

Tenders are to be returned to the India Store Department, Bromyard Avenue, Acton, W.3, so as to reach them by 2 p.m. on Monday 30th January 1961.

Specimen copy of the above enquiry can be seen at the Engineering Branch, of India Store Department, under the following reference : 2072/60/ENG.3/SGH. E7461

### INDIA SUPPLY MISSION

**ELECTROSTATIC SEPARATORS**

The India Supply Mission Washington D.C. invites TENDERS for the SUPPLY of equipment stated below required for the Streptomycin Project of Hindustan Antibiotics, Ltd.

ELECTROSTATIC SEPARATORS

Forms of Tender may be obtained from the India Store Department (CDN Branch) Government Building, Bromyard Avenue, Action, London, W.3, upon a payment of a fee of 7s. 2d. which is not returnable. Tender No. SE291 (CDN) must be quoted in all applications. Tender closing date in Washington 9th Feb. '61. E7452

## EDUCATIONAL

**A.M.IMECH.E., B.SC.,** City and Guilds, &c., Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent. successes. 148-page prospectus, free on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London, W.8. E114 E

### COLLEGE OF AERONAUTICS

**TWO-YEAR DIPLOMA COURSE, 1961–1963**

Applications are invited from suitably qualified men and women who wish to enrol for the TWO-YEAR DIPLOMA COURSE which begins in October, 1961.

This post-graduate course in Aeronautical Science and Engineering is intended primarily for University Graduates in Engineering, Science or Mathematics. Technical College students and others who possess a Higher National Certificate, Diploma, or equivalent qualification and attain the required entrance examination standard may also be accepted. The curriculum includes the subjects of Aerodynamics, Aircraft Design, Electrical and Control Engineering, Materials, Production and Industrial Administration and Aircraft Propulsion in all of which subjects a major specialisation may be taken. Lectures and laboratories in Mathematics and Flight are obligatory for all students.

All applications will be considered by the Board of Entry which may call candidates to attend at the College for written Entrance Examination in Engineering, Physics, Mechanics, and Mathematics, to be held on Monday, 27th March, 1961. Exemption from this examination will normally only be given to candidates possessing 1st or 2nd Class Honours Degrees in Science or Engineering, or reading for Honours Degrees. The Board may also require attendance for personal interview at a later date.

Candidates who possess Bachelors Degrees with 1st and 2nd Class Honours in Aeronautics, and also in Science or Engineering if they have adequate post-graduate experience, may at the discretion of the Board of Entry be accepted for entry to the second year of the course and qualify for the Diploma (D.C.Ae.).

Further information about the course and forms of application, which must be completed and returned not later than Saturday, 4th March, 1961, may be obtained from The Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks. E7450 E

## SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

**A SMALL OLD-ESTABLISHED ENGINEERING COMPANY** in Central London, requires a capable and qualified ENGINEER who would be able to prepare schemes, supervise the designing and costing of check weighing, auto sacking and such like installations. Mechanical, electrical and electronic knowledge necessary. The company wishes to obtain the services of an energetic man who, after a period to prove his suitability, could be appointed to the Board as a Technical Director.—Fullest particulars to BOX No. E3122, " The Engineer." A

**DRAUGHTSMAN** required by the British Drug Houses Ltd., preferably with experience in Plant Layout and Special Purpose Machine Design. Must be able to take Site Dimensions. O.N.C. minimum qualification. Five-day week, Canteen, Sports Club, Pension and Profit Sharing Schemes.—Apply in writing, stating age, experience and salary required to the Office Staff Manager, Graham Street, City Road, N.1. E7430 A

**ENGINEER SURVEYORS** required in Midlands and South for boiler and/or crane and lift inspections. Applicants (aged 26 to 33 years) must have served apprenticeship and have either 1st Class M.O.T. Certificate or H.N.C. with appropriate practical experience. Salary £825 rising to £1225 ; non-contributory pension scheme.—Apply to Chief Engineer, Accident Dept., Royal Exchange Assurance, 92 Cheapside, London, E.C.2. E7457 A

## SITUATIONS VACANT

**BBC** requires ENGINEER, Building Department to arrange and supervise contracts for installation and maintenance of lifts, maintenance of boiler, heating and ventilation services, refrigeration plant, gas services &c., in the London area. Work includes liaison duties with Departments concerned with the day to-day operation and upkeep of plant and services. Applicants, aged 35/45, should have commenced their careers with a menchanical engineering apprenticeship, preferably in heavy electrical industry, and have had considerable experience as a works engineer dealing with operation and maintenance of all building services. Salary scale £1230 to £1580 p.a. —Write for application form to Engineering Recruitment Officer, Broadcasting House, London, W.1, quoting ref.: EX.60.60.Eng. E7455 A

**ENGINEERING INSURANCE.** Applications are invited from Mechanical Engineers not over 35 years of age, who having served an apprenticeship with Crane and Lift Makers have a sound theoretical and practical knowledge of Cranes, Lifts, Lifting Machines and their maintenance, and are qualified to Higher National Certificate Standard, for a vacancy as ENGINEER SURVEYOR based in the Stoke-on-Trent district. The position is permanent, pensionable, with salary scale of £825 rising to £1225 per annum, plus expenses and allowances.—Apply in own handwriting to BOX No. E7417, " The Engineer." A

**ENGINEERING INSURANCE COMPANY** invites applications from Engineers not over 35 years of age who possess First Class M.O.T. Certificate (Steam) for position as MECHANICAL ENGINEER SURVEYOR in Bristol and surrounding areas. Progressive salary scale commencing at £825 rising to £1225 per annum, plus other expenses and allowances. Non-contributory pension scheme. —Apply in own handwriting to The Northern Assurance Company Limited, 1, Moorgate, London, E.C.2. E7416 A

**FUEL TECHNOLOGIST** required by the National Coal Board, Divisional Marketing Department, Edinburgh. Salary within the scale £1300 to £1825 per annum. The successful candidate will advise on and deal with technical matters relating to the use of coal or coke in boilers, furnaces, &c. Membership of the Institute of Fuel or similar qualifications, together with considerable experience, an advantage.—Applications stating age, education, qualifications, experience, present post and salary, to Staff Department, National Coal Board, 3 Eglinton Crescent, Edinburgh, 12. E7449 A

**QUALIFIED ENGINEER** required with drive and ability to take position of responsibility in company engaged in wide variety of small plant projects. Near Brighton.—BOX No. E7462, " The Engineer."

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Manufacturers of Plain Bearings, have a vacancy in their Research and Development organisation for a

**SENIOR RESEARCH ENGINEER**

responsible to the Manager, Engineering Research Department.

The S.R.E. will build up and lead a small team to carry out research and development in the field of piston engine bearings. He will also keep abreast of external work in this field and assist his Manager to assess commercial and research implications of data from inside and outside the Company.

Applicants must have a degree in Mechanical Engineering or the equivalent and have at least 2 years experience of research and/or development work on piston engines or lubrication or plain bearings.

Age 27 and over. Salary in the range of £1350 to £1750 per annum. Apply for application form to

**Personnel Division,**
**The Glacier Metal Company Limited,**
**Alperton, Wembley, Middlesex,**
*quoting Ref. HQPD/SRE.*

E7464 A

**HOWDEN**

James Howden & Company, Limited, have a vacancy for a

**WELDING DEVELOPMENT ENGINEER**

This is a new appointment and candidates should have industrial experience of modern welding techniques and application, automatic and semi-automatic processes, supervision of welding, modern destructive and non-destructive examination, ability to organise weld investigation and determine welding procedure, to test welder personnel. Membership of a Professional Institution is desirable and applicants should be of potential managerial calibre. Good salary and conditions of service.—Apply Personnel Manager, James Howden & Company, Limited, 195, Scotland Street, Glasgow, C.5, giving full details of career to date.

E7440 A

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## COMPANY MEETING

# HEENAN GROUP

## CONTINUED EXPANSION

The 58th ANNUAL GENERAL MEETING of Heenan Group Limited was held on December 19 at Worcester, MR. CHARLES L. HILL, the chairman, presiding.

The following is a summary of his circulated statement :—

The Group net profit, before taxation, of £564,387, exceeds the record achieved last year of £521,469. After providing for taxation, which takes £281,639 against £262,589, the net profit of the Group is £282,748 compared with £258,880.

The whole of the share capital of Armstrong, Stevens & Son Ltd., of Willenhall and Birmingham, was acquired during the year. The accounts do not include a full year's earnings of this new subsidiary.

The Group order position is most satisfactory with a balance of orders outstanding at the close of the year of £4,400,000. Orders received during the year from home and overseas exceeded £6,000,000. The subsidiaries are well represented abroad but the support of directors and executives is often necessary ; on average two overseas visits have been made every week covering all Europe, Russia, the Middle East, North and South America, India and Pakistan.

### REVIEW OF OPERATING COMPANIES

**Heenan and Froude Limited** has had an active year with demand for most of its specialised manufactures at a high level and with production limited only by the shortage of skilled men.

*Engine Test Plant :* an important advance has been made in the field of hydraulic dynamometers after three years of development. Known as the P.T. Dynamometer, the first production model has been installed at London Airport for B.E.A. Jet engine test plant for Conway engines has been supplied to Rolls-Royce Ltd., another of very modern design to Aerolineas Argentinas. High-speed Froude Dynamometers have been exported to Europe with ratings as high as 10,000 h.p. at 10,000 r.p.m. and a new type of Roller Car Tester built.

*Eddy-Current Couplings :* sales rose to a new record level and these couplings are being constantly applied to new industries finding useful applications for this speciality.

*Industrial Coolers* sales were up by a third on the previous year.

*Automatic Wire and Strip Forming Machines :* sales remained steady at the previous year's level.

*Municipal Engineering :* Several contracts are in hand and a number of promising projects are under consideration.

**Fielding and Platt Limited** ended the year with a good order book, the bulk of current contracts being for delivery within 12 months. The prospects for maintaining a satisfactory order book appear reasonably good. Two large presses have been delivered and a complete hydraulic power installation despatched to the Durgapur Steel Works. An entirely new design of self-contained extrusion press has been delivered to the Midlands and a large order received for three extrusion presses for Switzerland.

**Court Works Limited,** specialists in malleable iron and grey iron casting, has well maintained its output and sales. An additional mechanised foundry is being built for the production of pearlitic and blackheart malleable castings.

**Morton Machine Co. Ltd.** had a satisfactory year's trading. The order book position is very healthy and prospects for the coming year encouraging.

**Iwel Engineering Limited** increased its sales of Abattoir and Animal By-Product equipment and orders received were up by over a third, nearly half of the total being for export.

The order books of **Armstrong Stevens & Son Ltd.** have been considerably improved since the acquisition of this new subsidiary in January.

**Associated Locomotive Equipment Ltd.** continues to experience difficult trading conditions and its future depends upon new products outside the railway field.

The report was adopted and a final dividend of 8 per cent. on the increased ordinary capital was approved.

**Classified Advts. continued on page 84**

SITUATIONS VACANT

## BRITISH CELLOPHANE LIMITED

require a

## TECHNICAL SERVICE MANAGER

Applications for the position of Technical Service Manager are invited from men, aged 30/40, having the following qualifications :

A good Science or Engineering degree.
Successful Management experience.
A balanced interest in current market problems and long term use development.
Enthusiasm, drive, and ability to get on well with people.
A practical knowledge of packaging—particularly in respect of Plastic and/or Cellulose films would be an advantage.

The Technical Service Manager will be based on London, W.1, and will be responsible for departmental control of Technical Service Representatives, a Laboratory and a Machine Development Section. He will be required to establish and maintain first-class relationship with the Company's customers both in the United Kingdom and overseas by personal contact where necessary. Interviews will take place in London.

**Applications to : Personnel Officer, British Cellophane Limited, Bridgwater, Somerset.** E7451 A

## LAPORTE CHEMICALS LIMITED

*(a member of the Laporte Group of Companies)*

Require SENIOR

## MECHANICAL ENGINEERING DRAUGHTSMEN

for interesting work on large chemical plant installations. Experience in the type of work is desirable but not essential and applicants with general mechanical engineering experience will be favourably considered. The posts offer opportunities and salaries consistent with experience and ability. Modern offices situated in the London E.C.4. area. Five-day week and superannuation scheme.

Applications, which will be treated in the strictest confidence, giving details of age, qualifications and experience and quoting ref. LCL/TE2/1 should be addressed to **The Group Personnel Manager, Laporte Industries Limited, Hanover House, 14, Hanover Square, London, W.1.** E7423 A

## SENIOR PROJECT ENGINEER

required for the Central Engineering organisation of an active and flourishing Chemical concern in the North of England with international interests.

The duties attached to the post are the direction and co-ordination of the engineering activities of a group of projects concerned with the Company's expansion at home and overseas. The post is primarily concerned with design and procurement and not directly with site work.

A wide engineering experience is essential, including Civil, Electrical and Instrument engineering, with emphasis on Mechanical Engineering Design and Chemical Plant layout.

Applicants must be University graduates in Mechanical/Electrical Engineering and have served an apprenticeship, followed by at least ten year's experience in the Chemical industry.

A salary of the order of £2,500 is offered and interested Engineers who fulfil the above qualifications may write in strictest confidence to BOX No. E7405, " The Engineer." A

## LAPORTE CHEMICALS LIMITED

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for interesting work on large chemical plant installations. Candidates aged between 30 and 40 years should be experienced in plant layout and vessel design and familiar with British and American Codes of Practice. They should be first-class men of H.N.C. Standard, capable of controlling a section of draughtsmen and working under the direction of a Project Engineer.

The positions are permanent and attractive salaries will be offered to the selected applicants. Modern offices situated in the London E.C.4. area. Five-day week and superannuation scheme. Applications will be treated in the strictest confidence.

Details of age, qualifications and experience, and quoting reference LCL/TE2/82 should be sent to the Group Personnel Manager, **LAPORTE INDUSTRIES LIMITED,** Hanover House, 14 Hanover Square, London, W.1. E7411 A

SITUATIONS VACANT

## HOWDEN

James Howden & Company, Limited have vacancies for

## MANUFACTURING DEVELOPMENT ENGINEERS

The Company are manufacturers of industrial fans, preheaters, precipitators, dust collectors, compressors, turbines etc., and these engineers are required to study problems arising in Fabrication, Press-Work, Machining and Assembly of these products. Applicants should be of degree standard, and graduates or members of a professional institution. The ability to write clear concise reports is an essential qualification. The posts offer good prospects of advancement for young engineers with drive and ability.

Apply Personnel Manager, James Howden & Company, Limited, 195, Scotland Street, Glasgow, C.5., giving full details of career to date. E7439 A

## MOBBS & LEWIS, LTD.,

WOOD LAST MANUFACTURERS, CARRINGTON STREET, KETTERING.

Applications are invited for position of

## Qualified Development and Maintenance Engineer,

eventually to be in complete charge of modern engineering department serving three wood-working factories. A knowledge of hydraulics, compressed air tools and power would be highly desirable. Applicant's qualifications should include preferably University degree, but at the least H.N.C. in Mechanical Engineering or equivalent City and Guilds Certificate with a high standard of school educational achievement. Position eligible for pension scheme, and successful applicant will be directly responsible to the Directors.

Applications to Mr. H. E. B. Butlin, Managing Director. E3133 A

## SITUATIONS WANTED

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E194 RD

## PATENTS

**THE PROPRIETOR** of British Patent No. 755082, entitled " SUBSURFACE WELL TOOLS," offers same for license or otherwise to ensure practical working in Great Britain.—Inquiries to Singer, Stern & Carlberg, 140 So. Dearborn Street, Chicago 3, Illinois, U.S.A. E7429 H

**WANTED BY MEDIUM SIZE ENGINEERING FIRM** with Machining and Fabricating capacity Patent to Purchase or Operate under Licence.—BOX No. E7458, " The Engineer." H

## MISCELLANEOUS

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RHODES Open Fronted Upright Bench Punching Press, motorised for 400/3/50 supply, pressure exerted approx. 2 tons, stroke ¼in., adjustment to table ¼in., table 9in. by 4¼in., hole in table 1in. by 3in., weight approx. 3½ cwt.

TWO NEW LEN100/320, Open Fronted Inclinable Power Presses, motorised for 400/440/3/50 supply, pressure exerted 100 tons, depth of throat 12¼in., adjustment of stroke 13/16in. to 5¼in., table 23¾in. by 35 7/16in., hole in table 13¾in. diameter, weight approx. 147 cwt.

FROST Power Geared Swing Beam High-Lift Universal Folding Machine, motorised for 400/440/3/50 supply, capacity 10ft. by 3/16in. mild steel, adjustable for sharp and round bends, clamping beams swings out for removal of trunk sections, with adjustable back gauge, weight approx 6 tons.

PELS Double Geared All Steel Double Ended Angle and Tee Iron Cropping Machine, motorised for 400/3/50 supply, on turntable base for positioning in any direction, crops angles 7in. by 7in. by ¾in. or 6in. by 6in. by ¾in., tees 6½in. by 6½in. by ¾in., on the square and on the bevel, weight approx. 105 cwt.

BRADLEY & CRAVEN Press Brake, motorised for 400/440/3/50 supply, max. pressure approx. 65 tons, forming capacity 10ft. by 12 S.W.G. over die opening of ¾in., or 8ft. by ¼in. over die opening of 1¼in., tee slotted bed, length of bed and ram 120½in., width of bed 5in., weight approx. 8½ tons.

CRAIG & DONALD Deep Gap Guillotine Shearing Machine, motorised for 440/3/50 supply, capacity 14ft. by ¼in., with automatic hold-down and adjustable gauges, complete with three spare sets of blades, weight approx. 11 tons.

Photographs of the above are available.

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OVERHEAD CRANES.—25-ton Girders and end carriages, with 60 h.p. motors, 95ft. 10in. span; 25-ton Clyde, 21ft. 9in. span, new 1954; 20-ton Vaughan, 42ft. 3in. span, unused (2); 20-ton King, 42ft. 3in. span, 400/3/50; 10-ton Heywood, 34ft. span, unused; 10-ton Morris, 32ft. 10in. span, 400/3/50; two 10-ton, 60ft. span, 1955; two 7-ton, 37ft. span, 1950; Wharton, 7½-ton 25ft. span, 400/3/50; 5-ton, 37ft. span, 1944; 5-ton Henderson, 24ft. 7in. span, 1946; 5-ton King, 29ft. 3in. span, power hoist, hand travel; 5-ton Morris, 28ft. 6in. span, power hoist, hand travel; 4-ton Morris, 19ft. span, 220V d.c.
DERRICK CRANES.—7-ton Henderson, 110ft. jib, electric, 1952; 7-ton Anderson-Grice, 100ft. jib, electric; 5-ton Butters Grabbing, 80ft. jib, electric; 5-ton Wilson, 70ft. jib, electric; 3-ton Smith, 48ft. jib, electric; 3-ton Rushworth, 50ft. jib, hand; 15-cwt. Anderson-Grice, 30ft. jib, hand.
RAIL CRANES.—18-ton Brownhoist, steam, 50ft. jib; 10-ton Grafton, 34ft. jib, diesel conversion; 8-ton Wilson, steam, 35ft. jib; 5-ton Smith, 50ft. jib (2).
LOCOS.—Fowler diesel, 150 h.p. (2); Barclay & Ruston, 80/88 h.p. diesel; Bagnall, 14in. by 22in. (two oil-fired, one coal), Peckett steam, 7in. by 12in., 1941; 4 Logan battery-operated, 24in. gauge, 3-4-ton cap.; 3 Ruston diesel 16/20 h.p., 24in. gauge; also 2 miles 20 lb. and 1200 yds. of 25 lb. by 24in. gauge track, Bogies, Wagons, &c.
STEEL PIPING.—Large stocks including following: 20,000ft. 14in. galvanised "A."; 20,000ft. scaffolding; 30,000ft. 3in. black; 15,000ft., each 6in., 3/16in., ¼in., 5/16in., unused; 5000ft., 8in. unused; 2000ft., 10in., 12in., 16in., seamless; 200ft., 24in. by ¼in. welded, unused; 1000ft., 30in. by ¼in. welded, unused; 2500ft., 27in. welded flanged; 500ft., 36in., unused; 500ft., 42in. by ¼in. riveted; 100ft., 48in. by ¼in. welded, unused; 150ft., 60in., welded; 20in., 24in., 26in., 27in., 28in., bitumen-lined, unused. Full list on request.
CAST IRON PIPES.—Large stocks all sizes up to 24in. flanged and s.s., including 150 by 18ft. lengths, 6in. Stanton class "B" Spigot and Socket, unused. Immediate delivery.
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STORAGE TANKS.—300 cylindrical and rectangular, up to 12,000 gallons for oil and petrol, also sectional steel and cast iron up to 50,000 gallons.
MACHINE TOOLS.—Heenan & Froude Dynamometers, 1500 h.p. maximum, 18in. Dial Indicator (three); Pels Punch and Shears, ¼in. capacity; nine new 2 cwt. and 1 cwt. Pneumatic Hammers; Bonn Hydraulic Tube Bender up to 20ft. by 4in. bore; Berry Guillotine capacity 4ft. by 1in.; Rushworth Guillotine, 6ft. by ¼in., Bliss 70-ton power press; 3 Bliss No. 304 vertical single action drawing presses, 7½in. stroke; 7ft. by 1in. Plate Flattening Rolls; 9 roller flatteners, 2ft. by ¼in. capacity.
AUTOCLAVES.—Two 26ft. by 9ft. dia. hinged doors; new 1948, about 45 lbs. working pressure; jacketted, autoclave, 12ft. by 7ft. diameter, bolted lid, approx. 60 lbs. steam pressure.

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*By Order of the Secretary of State for War*

GOVERNMENT SURPLUS STORES

SALES BY AUCTION

| | | *Main Location* | *Auctioneers* |
|---|---|---|---|
| January 4 1961 | Miscellaneous stores. | Northern Command Ordnance Sub. Depot, Barlow, Nr. Selby, Yorks. | BARTLE & SON (Dept. L), 50-52, Merrion Street, Leeds, 2. (Tel.: 20898.) |
| January 11 | Machine tools and miscellaneous stores. | Central Ordnance Depot, Tidworth, Central Ordnance Sub-Depot, Devizes. (Sale at Corn Exchange, Devizes.) | FARRANT, WIGHTMAN & PINNIGER (Dept. L), Market House, 2, Newport Street, Swindon. (Tel.: Swindon 5151/2.) |
| January 19 | Machine tools and miscellaneous stores including: | W.D. Storage Depot, Rotherwas, Hereford. | RUSSELL, BALDWIN & BRIGHT LTD. (Dept. L), 20, King Street, Hereford. (Tel.: 4366.) |
| | 6,500 tyres; Myford, Challenger, Excell, Churchill, Dean Smith & Grace and other lathes; Wolf & Jones grinding machines; Lang Sharpener, Geo. Robson coal elevator; generating sets; chain blocks; operators' seats; steel binning; wrist and stop watches; telescopes; balance and by-pass filter units; furniture and kitchen equipment; electrical and wireless spares; electric cable and self-winding cable reels; M.T. and aircraft spares. | | |
| January 27 | Miscellaneous stores. | Command Ordnance Depot, Coypool, Marsh Mills, Plymouth. (Sale at Kinterbury House.) | WOOLLAND SON & MANICO (Dept. L), Kinterbury House, St. Andrews Cross, Plymouth. (Tel.: 69292.) |
| February 1 | Machine tools and miscellaneous stores. | Technical Stores Depot, Old Dalby, Leics. (Sale at Melton Mowbray.) | SHOULER & SON (Dept. L), 1, Norman Street, Melton Mowbray, Leics. (Tel.: 3081.) |
| February 7-9 | Vehicles earth-moving equipment, mobile cranes and motor cycles. | W.D. Storage Depot, Raddington, Notts. | WALKER, WALTON & HANSON (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.) |
| February 10 | Miscellaneous stores. | Returned Stores Group, Reed Hall, Colchester, Essex. | FENN WRIGHT & CO. (Dept. L), 146, High Street, Colchester, Essex. (Tel.: 73171.) |
| February 14-15 | Machine tools and miscellaneous stores. | W.D. Storage Depot, Royal Arsenal, Woolwich, London, S.E.18. | FULLER, HORSEY, SONS & CASSELL (Dept. L), 10, Lloyd's Avenue, London, E.C.3. (Tel.: Royal 4861.) |
| February 21 and following days | Machine tools and miscellaneous stores. | R.O.F., Fazakerley. (Sale at Crane Theatre, Hanover Street, Liverpool). | J. H. NORRIS & SON (Dept. L), 9, Albert Square, Manchester, 2. (Tel.: Blackfriars 8373.) |
| February 28 | Miscellaneous stores. | 1 E.S.D., Long Marston, Nr. Stratford-on-Avon, Warwicks. (Sale at the Hippodrome, Stratford-on-Avon.) | LOCKE & ENGLAND (Dept. L), 166, Parade, Leamington Spa, Warwicks. (Tel.: 2833.) |

Application for catalogues, available 14 days prior to date of sale should be made only to the auctioneers shown above (price of catalogue 1s. 0d. P.O. only).

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E118 *i*

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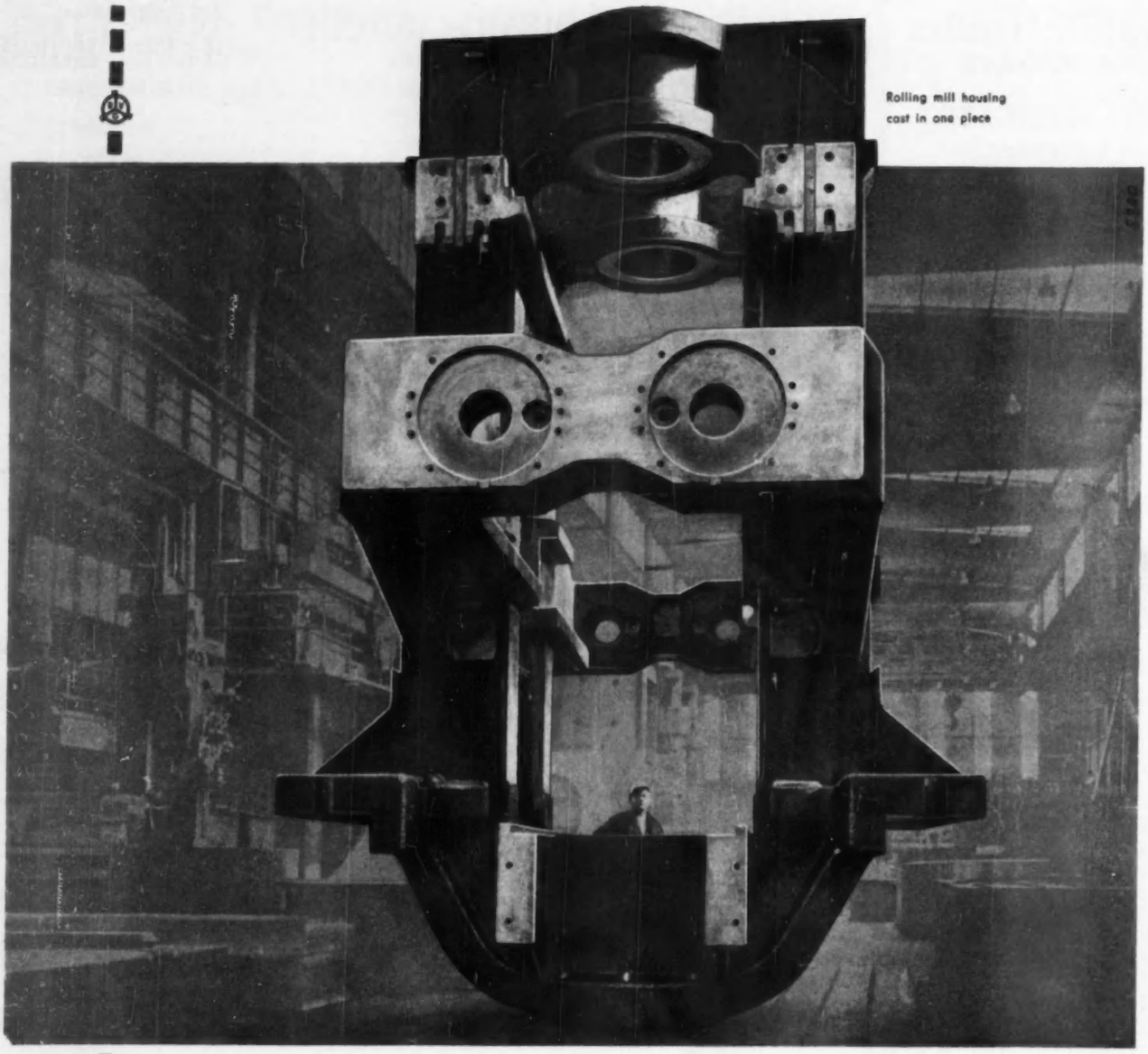

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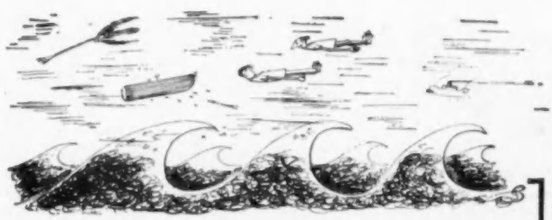
# INDEX TO ADVERTISERS


| | PAGE |
|---|---|
| Acciaieria E Tubificio Di Brescia | 30 |
| Adamson, Joseph & Co., Ltd. | 79 |
| Admel Tesa Tapes | 20 |
| Allen, W. H. Sons & Co., Ltd. | 38 |
| Anderson, C. F. & Son, Ltd. | 48 |
| Archdale, J. & Co., Ltd. | 6 |
| Associated Electrical Industries, Ltd. | 29-34-62 |
| Ashmore, Benson, Pease & Co., Ltd. | 9 |
| Auto Aero, Ltd. | 4 |
| Autometric Pumps, Ltd. | 22 |
| Automotive Products Co., Ltd. | 25 |
| Bailey, Sir W. H. & Co., Ltd. | 2 |
| Barnet Metal Co., Ltd. | 2 |
| Barr Thomson & Co., Ltd. | 24 |
| Barron, W. S. & Son, Ltd. | 25 |
| Birkett, Billington & Newton, Ltd. | 24 |
| Blackwell Bearings, Ltd. | 81 |
| Blakeborough, J. & Sons, Ltd. | 70 |
| Bochumer Verein A.G. | 86 |
| Booth, Joseph & Bros. | 67 |
| British Appliances Mfg. Co., Ltd. | 73 |
| British Industrial Engineering Co. (Staffs.), Ltd. | 53 |
| British Steam Specialties, Ltd. | 73 |
| British Steel Founders Association. | 31 |
| Broom & Wade, Ltd. | 18 |
| Brown, David, Corporation (Sales), Ltd. | 13 |
| Brown, N. C., Ltd. | 65 |
| Brownlie & Murray, Ltd. | 79 |
| Bullows, Alfred & Sons, Ltd. | 87 |
| Butcher, Henry & Co. | 85 |
| C. & M. Engineering Co., Ltd. | 22 |
| Carter, B. & F. & Co., Ltd. | 27 |
| Cary, W. E., Ltd. | 56 |
| Cattermole, H. S. & Co. (Hydraulics), Ltd. | 14 |
| Central Electricity Generating Board. | 51 |
| Clyde Crane & Booth, Ltd. | 67 |
| Clyde Crane & Engineering Co. | 67 |
| Colt Ventilation, Ltd. | 3 |
| Consolidated Pneumatic Tool Co., Ltd. | 57 |
| Conveyor & Elevator Co. (1936), Ltd. | 15 |
| Coventry Climax Engines, Ltd. | Cover i |
| Cowlishaw, Walker & Co., Ltd. | 55 |
| Crofts (Engineers), Ltd. | 44 |
| Cross Manufacturing Co. (1938), Ltd. | 2 |
| Cull, W. B. & Sons, Ltd. | 50 |
| Demag A.G. | 17 |
| Dillon's University Bookshop, Ltd. | 83 |
| Dilloway, P. W., Ltd. | 20 |
| Drysdale & Co., Ltd. | 78 |
| Eagre Construction Co., Ltd. | 77 |
| Easton & Johnson, Ltd. | 46 |
| Electrical Power Engineering Co. (B'ham), Ltd. | 73 |
| Electronic Engineering | 48 |
| Entwistle & Gass, Ltd. | 47 |
| Farmer, Leopold & Sons | 85 |
| Ferranti, Ltd. | 10 |
| Filton, Ltd. | 47 |
| Fleming & Ferguson, Ltd. | 55 |
| Foord, John & Co. | 85 |
| Forster, T. S. & Sons, Ltd. | 66 |
| Fuller, Horsey, Sons & Cassell. | 85 |
| General Descaling Co., Ltd. | 33 |
| Girdlestone Pumps, Ltd. | 66 |
| Goodwin, R. & Sons (Engineers), Ltd. | 27 |
| Gordon Motors | 41 |
| Govan Shafting & Engineering Co. | 69 |
| Greening, N. & Sons, Ltd. | 39 |
| Guest Keen Iron & Steel Co., Ltd. | 71 |
| Gummers, Ltd. | 40 |
| Gwynnes Pumps, Ltd. | 52 |
| Hadfields, Ltd. | Cover ii |
| Halesowen Steel Co., Ltd. | 71 |
| Harlow, R. & Son, Ltd. | 27 |
| Harris-Walton Lifting Gear, Ltd. | 40 |
| Hayward, E., & Co. (Fabrications), Ltd. | 43 |
| Heenan & Froude, Ltd. | 83 |
| Herbert, A., Ltd. | 76 |
| Higgs Motors, Ltd. | 16 |
| Hill & Jackson (Springs), Ltd. | 80 |
| Hird-Brown, Ltd. | 55 |
| Hitachi, Ltd. | 49 |
| Howden, James, & Co., Ltd. | Cover vi |
| Hudson, R., Ltd. | 68 |
| Hunwicks, W. A. & Co., Ltd. | 73 |
| Hyde, R. Castings | 60 |
| Ince Forge Co., Ltd. | 79 |
| International Combustion, Ltd. | 12 |
| International Meehanite Metal Co., Ltd. | 59 |
| Ironsides Lubricants, Ltd. | 27 |
| Jellyman, S., Ltd. | 7 |
| Johnson & Phillips, Ltd. | 32 |
| Kempe's Engineers Year-Book | 39-79-83 |
| Klinger, Richard, Ltd. | Cover v |
| Lambhill Ironworks, Ltd. | 72 |
| Lanarkshire Bolt & Rivet Co., Ltd. | 59 |
| Lancaster & Tonge, Ltd. | 43 |
| Leeds Engineering & Hydraulic Co., Ltd. | 41 |
| Little, J. H. (Traction and Engineering), Ltd. | 66 |
| Lucas Industrial Equipment, Ltd. | 36 |
| Lynch, M. & Son, Ltd. | 4 |
| MacLellan, P. & W., Ltd. | 46 |
| Mannesmann-Meer A.G. | 11 |
| Maxseal Valves, Ltd. | 15 |
| McNair, D. G. & Co., Ltd. | 22 |
| McNeil, Charles, Ltd. | 69 |
| Micanite & Insulators Co., Ltd. | 39 |
| Morris, Herbert, Ltd. | 63 |
| Neco Geared Motors, Ltd. | 14 |
| Newbury Diesel Co., Ltd. | 65 |
| Non-Ferrous Die Casting Co., Ltd. | 22 |
| Nuclear Power Group | 54 |
| Parker, Frederick, Ltd. | 50 |
| Plant Engineers, Ltd. | 35 |
| Plenty & Son, Ltd. | 5 |
| Pollard, F., & Co., Ltd. | 80 |
| Pool, J. & F., Ltd. | 59 |
| Precision Rubbers, Ltd. | 41 |
| Priest Furnaces, Ltd. | 58 |
| Renshaw Foundry, Ltd. | 69 |
| Reynolds Tube Co., Ltd. | 15 |
| Roberts Bros. | 65 |
| Rocol, Ltd. | 28 |
| Roller Shutters, Ltd. | 30 |
| Rubber-By-Products (Warwickshire), Ltd. | 15 |
| S.W.F. | 7 |
| Schieldrop & Co., Ltd. | 4 |
| Scottish Machine Tool Corporation, Ltd. | 69 |
| Semtex, Ltd. | 26 |
| Shipham & Co., Ltd. | 4 |
| Simplifix Couplings, Ltd. | 7 |
| Sinex Engineering Co., Ltd. | 74 |
| Slingsby, W. & Co., Ltd. | 47 |
| Smedley Bros., Ltd. | 73 |
| Smith & McLean, Ltd. | 2 |
| Smith, Hugh, & Co. (Glasgow), Ltd. | 22 |
| Smiths Industrial Instrument Division | 40 |
| Steel Construction Co., Ltd. | 80 |
| Sterling-Safway | 19 |
| Sutcliffe Hydraulics, Ltd. | 27 |
| Swain, J., & Son, Ltd. | 81 |
| Tangyes, Ltd. | 8 |
| Tecalemit, Ltd. | 61 |
| Technoimpex. | 66 |
| Town, F. & Sons, Ltd. | 37 |
| Tudor Shearing Co., Ltd. | 48 |
| Turner Bros. Asbestos Co., Ltd. | 65 |
| V. W. Co., Ltd. | 76 |
| Vickers-Armstrongs (Engineers), Ltd. | 21 |
| Vokes Genspring, Ltd. | 45 |
| Ward, Thos. W., Ltd. | 84 |
| Weir, G. & J., Ltd. | 42 |
| Wellman Smith Owen Engineering Corporation, Ltd. | 75 |
| Wharton Crane & Hoist Co., Ltd. | 64 |
| Wheatley Kirk, Price & Co. | 85 |
| Wickman, Ltd. | 23 |
| Wiggin, H. & Co., Ltd. | 88 |
| Wilkinson Rubber Linatex, Ltd. | 77 |
| Worcester Valve Co., Ltd. | 43 |





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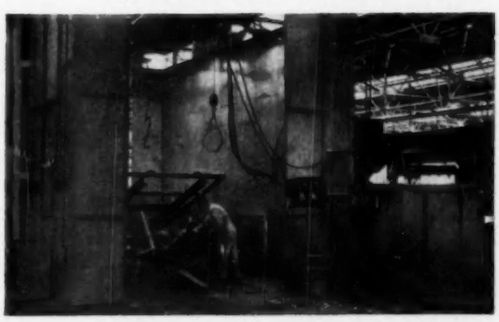

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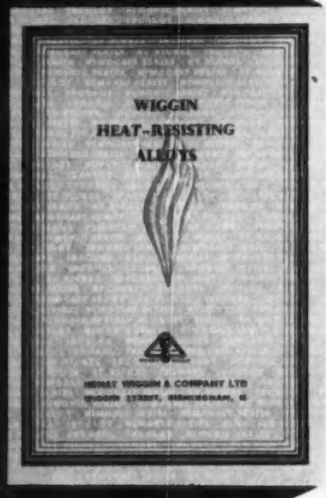


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